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Appendix J

Policy

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THE POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE ON THE UNITED STATES:

APPENDIX J - POLICY

Editors: Joel B. Smith and Dennis A. Tirpak

OFFICE OF POLICY, PLANNING AND EVALUATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
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MAY 1989

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PREFACE

The ecological and economic implications of the greenhouse effect have been the subject of discussion within the scientific community for the past three decades. In recent years, members of Congress have held hearings on the greenhouse effect and have begun to examine its implications for public policy. This interest was accentuated during a series of hearings held in June 1986 by the Subcommittee on Pollution of the Senate Environment and Public Works Committee. Following the hearings, committee members sent a formal request to the EPA Administrator, asking the Agency to undertake two studies on climate change due to the greenhouse effect.

> One of the studies we are requesting should examine the potential health and environmental effects of climate change. This study should include, but not be limited to, the potential impacts on agriculture, forests, wetlands, human health, rivers, lakes, and estuaries, as well as other ecosystems and societal impacts. This study should be designed to include original analyses, to identify and fill in where important research gaps exist, and to solicit the opinions of knowledgeable people throughout the country through a process of public hearings and meetings.

To meet this request, EPA produced the report entitled *The Potential Effects of Global Climate Change on the United States*. For that report, EPA commissioned fifty-five studies by academic and government scientists on the potential effects of global climate change. Each study was reviewed by at least two peer reviewers. The Effects Report summarizes the results of all of those studies. The complete results of each study are contained in Appendices A through J.

Appendix	**Subject**
A	Water Resources
B	Sea Level Rise
C	Agriculture
D	Forests
E	Aquatic Resources
F	Air Quality
G	Health
H	Infrastructure
I	Variability
J	Policy

GOAL

The goal of the Effects Report was to try to give a sense of the possible direction of changes from a global warming as well as a sense of the magnitude. Specifically, we examined the following issues:

- sensitivities of systems to changes in climate (since we cannot predict regional climate change, we can only identify sensitivities to changes in climate factors)
- the range of effects under different warming scenarios
- regional differences among effects
- interactions among effects on a regional level

- national effects
- uncertainties
- policy implications
- research needs

The four regions chosen for the studies were California, the Great Lakes, the Southeast, and the Great Plains. Many studies focused on impacts in a single region, while others examined potential impacts on a national scale.

SCENARIOS USED FOR THE EFFECTS REPORT STUDIES

The Effects Report studies used several scenarios to examine the sensitivities of various systems to changes in climate. The scenarios used are plausible sets of circumstances although none of them should be considered to be predictions of regional climate change. The most common scenario used was the doubled CO_2 scenario ($2XCO_2$), which examined the effects of climate under a doubling of atmospheric carbon dioxide concentrations. This doubling is estimated to raise average global temperatures by 1.5 to 4.5°C by the latter half of the 21st century. Transient scenarios, which estimate how climate may change over time in response to a steady increase in greenhouse gases, were also used. In addition, analog scenarios of past warm periods, such as the 1930s, were used.

The scenarios combined average monthly climate change estimates for regional grid boxes from General Circulation Models (GCMs) with 1951-80 climate observations from sites in the respective grid boxes. GCMs are dynamic models that simulate the physical processes of the atmosphere and oceans to estimate global climate under different conditions, such as increasing concentrations of greenhouse gases (e.g., $2XCO_2$).

The scenarios and GCMs used in the studies have certain limitations. The scenarios used for the studies assume that temporal and spatial variability do not change from current conditions. The first of two major limitations related to the GCMs is their low spatial resolution. GCMs use rather large grid boxes where climate is averaged for the whole grid box, while in fact climate may be quite variable within a grid box. The second limitation is the simplified way that GCMs treat physical factors such as clouds, oceans, albedo, and land surface hydrology. Because of these limitations, GCMs often disagree with each other on estimates of regional climate change (as well as the magnitude of global changes) and should not be considered to be predictions.

To obtain a range of scenarios, EPA asked the researchers to use output from the following GCMs:

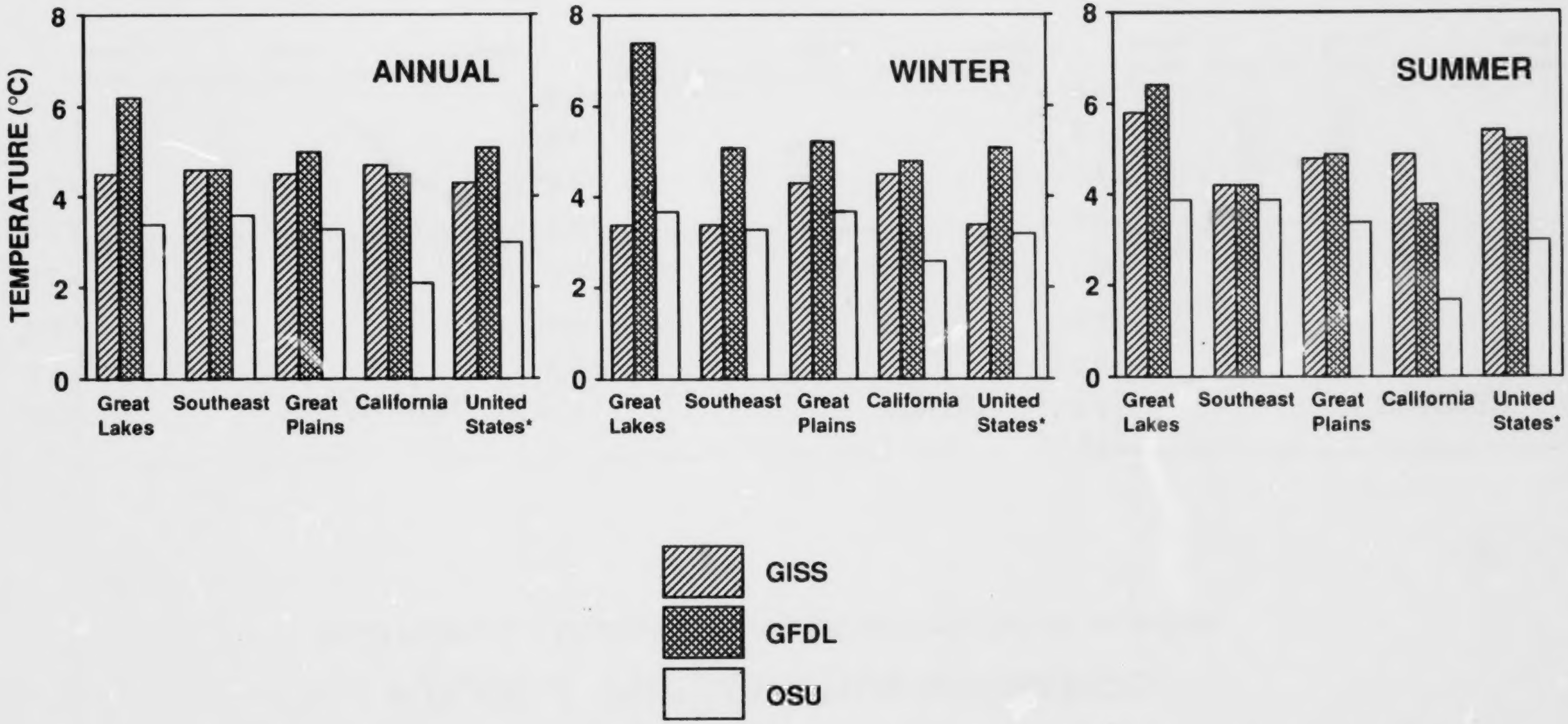
- Goddard Institute for Space Studies (GISS)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Oregon State University (OSU)

Figure 1 shows the temperature change from current climate to a climate with a doubling of CO_2 levels, as modeled by the three GCMs. The figure includes the GCM estimates for the four regions. Precipitation changes are shown in Figure 2. Note the disagreement in the GCM estimates concerning the direction of change of regional and seasonal precipitation and the agreement concerning increasing temperatures.

Two transient scenarios from the GISS model were also used, and the average decadal temperature changes are shown in Figure 3.

FIGURE 1. TEMPERATURE SCENARIOS

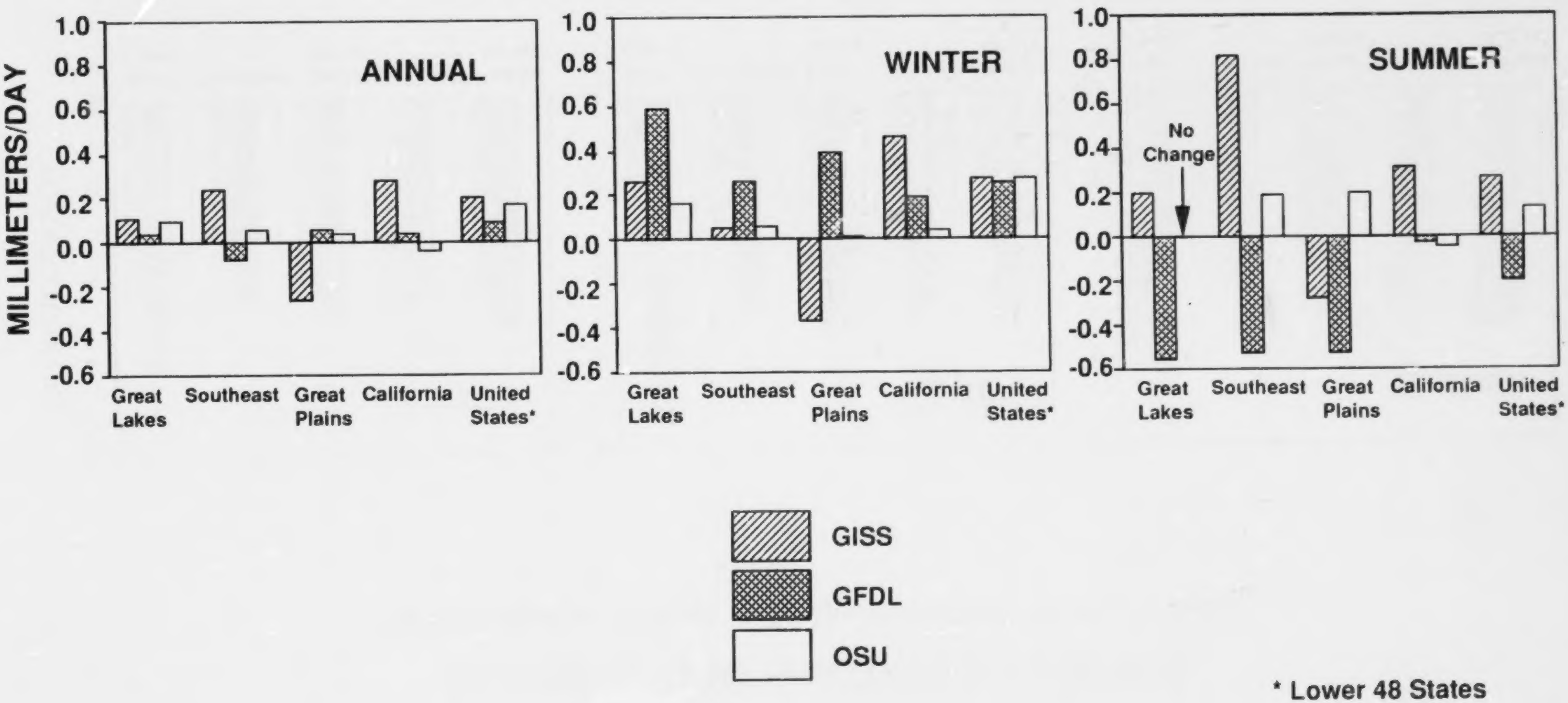
GCM Estimated Change in Temperature from $1xCO_2$ to $2xCO_2$



* Lower 48 States

FIGURE 2. PRECIPITATION SCENARIOS

GCM Estimated Change in Precipitation from $1xCO_2$ to $2xCO_2$



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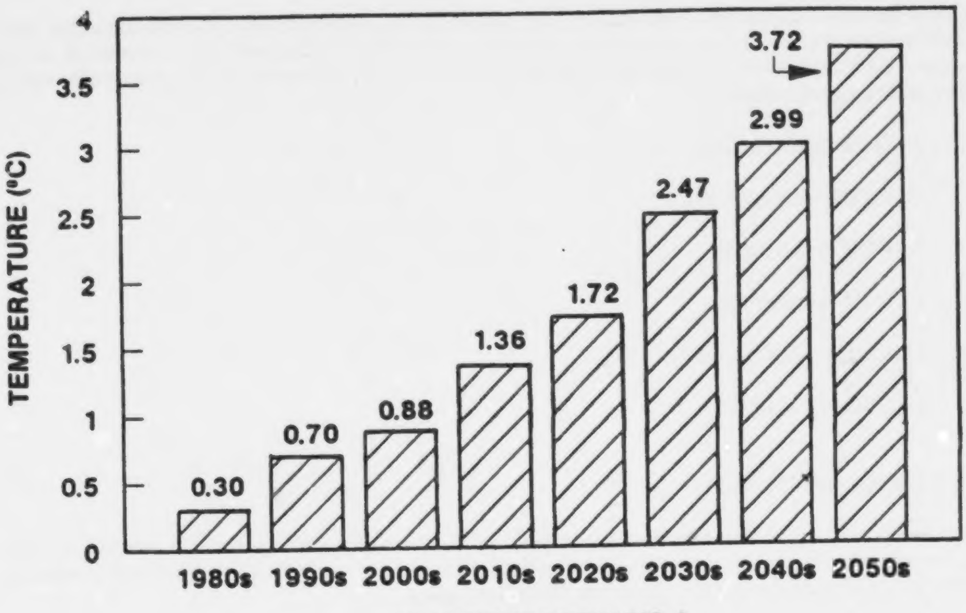
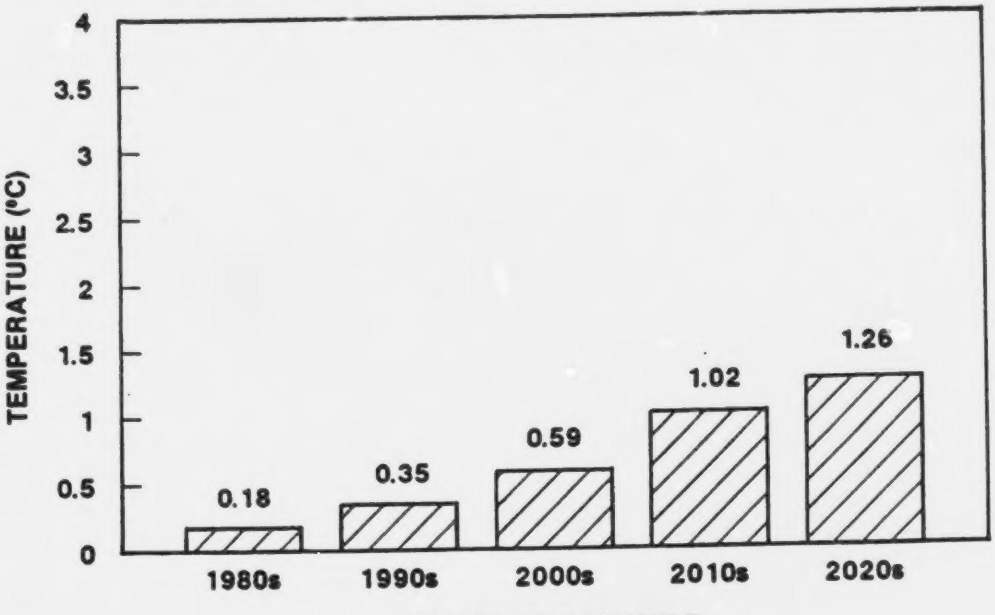


TRANSIENT SCENARIO A



TRANSIENT SCENARIO B

FIGURE 3. GISS TRANSIENTS "A" AND "B" AVERAGE TEMPERATURE CHANGE FOR LOWER 48 STATES GRID POINTS.

EPA specified that researchers were to use three doubled CO_2 scenarios, two transient scenarios, and an analog scenario in their studies. Many researchers, however, did not have sufficient time or resources to use all of the scenarios. EPA asked the researchers to run the scenarios in the following order, going as far through the list as time and resources allowed:

1. GISS doubled CO_2
2. GFDL doubled CO_2
3. GISS transient A
4. OSU doubled CO_2
5. Analog (1930 to 1939)
6. GISS transient B

ABOUT THESE APPENDICES

The studies contained in these appendices appear in the form that the researchers submitted them to EPA. These reports do not necessarily reflect the official position of the U.S. Environmental Protection Agency. Mention of trade names does not constitute an endorsement.

SOCIETAL RESPONSES TO REGIONAL CLIMATE CHANGE:
FORECASTING BY ANALOGY

by

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EXECUTIVE SUMMARY

This project was undertaken in an attempt to determine potential societal responses to the regional impacts of a carbon dioxide/trace gases-induced global warming by identifying several regional scenarios based on actual, prolonged, outlying climatic events that have occurred in recent times and by investigating the impacts of those events and the societal responses to these impacts. This approach is based on the assumption that the observed societal responses to impacts of several of these events could serve as analogues for an improved understanding of the possible societal responses to impacts that might be associated with a global warming of the atmosphere. This assessment can identify rigidities and strengths that may exist in the way society copes with the impacts of extreme (possibly unusual) events and may help to assess society's ability to deal with future unforeseeable climate-related anomalies, including extreme meteorological events.

The list of climate-related events that might serve as analogues and provide input for scenario construction includes the following: the depletion of the Ogallala Aquifer, changes in streamflow in the Sacramento and Colorado River Basins, sea level rise and coastal subsidence in Louisiana, changes in the Mississippi River system, changing levels of the Great Salt Lake and the Great Lakes, a set of nearly consecutive annual freezes in Florida, and water shortages in a metropolitan area in northern Virginia.

There has been considerable speculation about what the warming of the atmosphere by several degrees Celsius will do to regional climate and to human activities presently attuned to that climate. The basis for that speculation (and that is all it is at present) comes from general circulation model (GCM) output as a result of sensitivity studies associated with a CO_2 doubling. It has also come from historical analogues such as the Medieval Optimum that occurred earlier in this millenium. Other climate analogues include the Altithermal as well as epochs tens of thousands of years ago when the earth's atmosphere was much warmer than it is at present.

The GCMs are better at dealing with temperature than they are with rainfall.

Although the outputs from the various GCMs do not necessarily agree with each other on temperature, they do fall within a well-defined range. There is considerable disagreement as to how a global average warming might translate into climate changes at the regional and local levels. This, however, has not hindered speculation about regional and local climate changes and their socioeconomic impacts.

GCM-generated scenarios have a considerable amount of scientific credibility in the non-scientific community, including policymakers. However, some potential changes in climate several decades into the future that are being suggested from the scientific community are beyond the scope of experience (and possibly education) of decisionmakers. Thus, they lack political and social credibility and this leads to a real problem for decisionmakers. Either decisionmakers accept them unquestioningly as the product of an objective scientific community that lays all its information on the table, including questions of uncertainty and perhaps even dissenting views, or they disregard them as speculative ventures of scientists.

Scenarios about future worlds based on human experience--analogies or case scenarios--have the political and social credibility that computer-generated scenarios lack. Decisionmakers who have been directly involved in problems generated by climatic anomalies in the recent past have already been using that experience as a guide to dealing with current issues. Such experience is being passed on to prospective decisionmakers through education, just as the experiences of the Thirties Great Plains drought have been carried from one generation to the next. Yet, when compared to scientific models, the experience-based scenarios seem to lack scientific credibility. They are often discounted with such statements as "the past is no guide to the future." This adage has been reinforced by the view that, with a changing climate, the past will not be representative of the future.

The purpose of looking back is to determine how flexible (or rigid) societies are or have been in dealing with climate-related environmental changes. Societies everywhere have already shown the propensity to prepare for the last climate anomaly by which they were affected. However, such anomalies seldom seem to recur in the same place, with the same intensity, or with the same societal impacts. We must be aware of past events but we must not get drawn into preparing for them. Our decisions today must take into consideration the need to maintain as much flexibility as practicable in the face of future unknowns.

Both approaches (modeling and contemporary analogies) have their good points and their shortcomings in producing scenarios. It is important that they both be taken into consideration at the same time in order to maintain an air of reality about discussions of future climate change. Either set of scenarios considered by itself can be misleading; focusing on one particular scenario of the future would most likely lead to very different policy responses from those involving a focus on a different but equally plausible scenario. We must find a way to combine the strengths of the two approaches.

Forecasting the future by analogy can be a fruitful approach to improve our understanding of how well society is prepared to cope with the presently unknown regional characteristics of a potential climate change some decades in the future. However, we must not expect analogies to tell us what that future will be. No forecasting system has been successful in that endeavor. Analogies can, however, help us to identify societal strengths and weaknesses in coping with extreme meteorological events so that we can reinforce those strengths and reduce the weaknesses.

GENERAL FINDINGS[1]

These general findings serve to highlight some of the key points made in the papers that have been prepared for the ESIG/EPA Regional Scenarios Project. In the next section of the executive summary each research paper and its findings has been summarized. These case studies and their executive summaries provide the richness of information on responses to climate-related environmental changes that occur at the local and regional levels.

Because we are concerned about the local and regional effects of and responses to a global climate change, there will be a need at the outset to identify how well societies have in the past dealt with local climate-related environmental changes, regardless of cause. In order to add to the body of knowledge about societal responses to possible global climate change, it is important to know what that body looks like with respect to responses to climate variability and to extreme meteorological events.

These case studies underscore the importance of the involvement of the local and state levels of government in climate-related environmental problems. These are the levels at which such changes will ultimately occur. These are the levels at which societies will most likely respond, at least initially.

The importance of the local nature of societal impacts and responses to those impacts also underscores the need to generate awareness among decisionmakers at that level about what a global warming might mean to the expected continuance of their present-day activities.

There is a problem in some instances with conflicting signals. While the Great Salt Lake and the Great Lakes levels are now at or near record-setting levels, the scientific community suggests that with a global warming the levels of those lakes should decline. How credible can alarms about a global warming be to decisionmakers at the local level, when environmental changes at that level are seemingly contradictory to scientific projections about what should be happening?

In each case study a catalyst prompted action by people and their governments. In the case of Louisiana sea level rise/coastal subsidence the catalyst was not the gradual rise in sea level or the gradual pace of coastal erosion. It was the realization that two Louisiana parishes (counties) would most likely be underwater in about a century. In the Great Salt Lake situation that catalyst was not a gradual rise in lake level (which had been occurring since the early 1960s) but the sharp annual increases in lake level since 1982.

Each case study raised the issue of intergenerational equity. For example, several of the GCM models have suggested that there will be a "drying out" of the Great Plains in the event of a global warming. Users of the water from the Ogallala Aquifer must decide at what rate to drawdown the aquifer today (to produce crops that are in surplus and that demand low prices) or whether to save that finite water supply for use by future generations in those parts of the region overlying the aquifer where recharge rates are low.

In all of these cases ad hoc responses were favored over longer term planned responses. As a result, there has been a tendency to "muddle through." This has not necessarily been a bad response but it is probably more costly in the long run than putting a long-term strategy together in order to cope with climate-related environmental changes.

Several of these cases show that ad hoc decisions made in response to an environmental change have often built into the existing social structures an additional degree of rigidity that would in the long-term decrease society's ability to respond to changes.

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[1] Although the information in this report has been funded wholly or partly by the U.S. Environmental Protection Agency under Interagency Agreement No. DW 49932663-01-0, it does not necessarily reflect the Agency's views, and no official endorsement should be inferred from it.

The Florida case study points out that climate variability can adversely affect the economic competitiveness of climate-dependent industries. Such severe freezes as Florida witnessed in 1962 and in the early 1980s served as catalysts to accelerate economic and social changes at the local level, changes that may already have been under way but at much slower rates.

Coalition-building is an important part of creating an awareness of as well as coping with a climate-related problem. The Louisiana case study provides an excellent example of how a few concerned individuals in a parish were able to develop broader statewide interest in a set of problems that seemingly threatened only local populations and local political units. Coalition-building in Louisiana provides an interesting example to other states (such as Florida) that also face a variety of climate-related environmental problems.

Societies are constantly changing and they will continue to do so regardless of whether the global climate changes. It is important to take societal changes into account when considering societal responses to the impacts of climate variability, climate change, and extreme meteorological events.

It has been argued in the climate change literature either (1) that everyone will lose if the climate changes and therefore we should act now, or (2) that we must wait to identify what the regional impacts of such a change might be before we proceed to make policy to deal with climate change. The Colorado River study suggests, however, that even when the winners and losers have been identified there will be little interest on the part of the winners to alter their status in order to compensate the losers.

The following section presents a brief description and some of the key findings in an executive summary format of the case studies prepared for the ESIG/EPA project. The findings presented in the executive summary are based on the case studies carried out by the following scientists:

Regional Scenario Construction	Dale Jamieson Philosophy Dept. University of Colorado
Statistics of Climate Change	Richard Katz Environmental and Societal Impacts Group NCAR
Ogallala Aquifer Depletion	Donald Wilhite Center for Agricultural Climatology and Meteorology University of Nebraska
Sacramento River Basin	Peter Gleick Energy & Resources Group University of California--Berkeley
Colorado River Compact	Barbara Brown Environmental and Societal Impacts Group NCAR
Sea Level Rise and Coastal Subsidence	Mark Meo Science & Public Policy Program University of Oklahoma
Mississippi River Navigation	William Koellner U.S. Army Corps of Engineers Rock Island District

The Great Salt Lake	Peter Morrisette Environmental and Societal Impacts Group NCAR
The North American Great Lakes	Stewart Cohen Canadaian Climate Centre Downsview, Ontario
Florida Freezes	Kathleen Miller Environmental and Societal Impacts Group NCAR
The 1977 Occoquan Drought	Daniel Sheer Water Resources Management Columbia, Maryland

GLIMPSING THE FUTURE

Scenarios are one way of attempting to get a look at the future; numerical models are another way. Scenarios also include analogies. These can be referred to as case scenarios. They provide a way of "telling the story" about the future that model-generated scenarios cannot provide. Certain dangers are associated with the use of analogy-based scenarios, including stretching an analogy too far or selecting an analogy that is inappropriate. Appropriate use of scenarios can provide useful "stories" about the future and about how human populations respond to variations in environmental conditions.

If global warming is now occurring, it is not just something that is happening to people: People are implicated in bringing it about. In response to global warming, we can expect various modulations of human behavior. These modulations will in turn affect atmospheric conditions which in turn will affect human behavior, and so on. One consequence of this feedback between human behavior and atmospheric conditions is that in order to answer our question--how are humans likely to respond to environmental changes at the regional level brought about by a carbon dioxide/trace-gases induced global warming--we must gain insight into the interactions between climate and behavior.

The notion of a scenario is widely used in the climatology literature. Unfortunately, it is often used in vague and misleading ways. The concept of a scenario is a rich one and of great utility in a number of different areas of investigation.

Scenarios are sketches or outlines of stories rather than abstract sets of statements or propositions. They are constructed in order to serve some purpose, and they are told from a point of view. They bring together diverse information and engage our imagination about a natural or expected course of events. They are neither predictions nor fantasies; they are plausible stories.

Good analogical reasoning does not concern the number of similarities two objects share, but rather the significance of the important similarities. Identifying important similarities involves pragmatic considerations regarding contexts, interests, and purposes. These considerations cannot be taken up in any purely structural account.

There are four advantages of the case scenario approach: wealth of detail, integration of a broad range of knowledge, multiplicity of perspectives, and communicability and usability. There are, however, dangers to be avoided when using the case scenario approach: lack of definition, straining an analogy, and failure of analogy.

STATISTICS OF CLIMATE CHANGE: IMPLICATIONS FOR SCENARIO DEVELOPMENT

The nature of the information about future climate that would be needed for societal impact studies is considered. Keeping these needs in mind, the adequacy of the output from climate experiments based on general circulation models (GCMs) is assessed. The prospects for resolving the so-called "first-detection" problem, concerned with identifying and attributing any climate change that might have taken place by subjecting the recent observational record of climate to statistical analysis, are discussed. Explanation is given as to why it is inherently more difficult to make statistical inferences about changes in climate variability than about changes in climate means. The problem of how best to estimate the probabilities of various climate events is examined from a decision-analytic viewpoint.

GCM climate experiments do not currently produce information in a form that is useful for societal impact studies. This should not be surprising because GCMs were developed with the intention of aiding in basic research about the atmosphere rather than with the needs of climate impact research in mind. It is not at all clear that GCMs will be able to better meet these requirements in the near future.

The projection of future climate on the basis of currently observed trends is not necessarily justified. This suggests a fundamental quandary concerning the best way to estimate the likelihood of climate events. Should decisionmakers retain the "stationarity" hypothesis that the climate is not changing in any permanent fashion and estimate the probabilities of occurrence of future climate events using the observed frequencies of occurrence of these events in the historical record? Or should these probability estimates be based only on the relatively recent historical record or on the extrapolation of an apparent trend or cycle?

Several fundamental issues need to be resolved before impact studies should rely on scenarios of future climate based on GCM climate experiments or based on the extrapolation of observed climate change. However, the utility of the case scenario approach is not solely dependent on whether the climate event considered is analogous in some respects to an anticipated future climate change. Instead, the value of this approach rests more in providing information about how society has dealt with climate events in the past, regardless of whether the specific event being examined is at all analogous to events of interest in the future. Given the lack of a reliable way of projecting future climate change, perhaps the reliance on such case studies is a viable approach to climate impact assessment.

DEPLETION OF THE OGALLALA AQUIFER

The depletion of the aquifer represents an important change in the water balance of the Great Plains region. The thickness of the aquifer that underlies the region is not uniform. Thus, people in the Texas Panhandle, where the aquifer is relatively thin and has in the past been heavily used, are much more directly affected by a drawdown of groundwater than those in Nebraska, a state which possesses a major share of the aquifer's resources and high aquifer recharge rates. Both local and federal responses and policy studies of the agricultural future of the region are examined to investigate how climate has been taken into account in the planning process and how perceptions affect and are affected by the political and social acceptability of policy options.

The drawdown of the Ogallala Aquifer raises an important issue that permeates discussions about the social and political responses to a global warming: discounting the future. Here is a good example of a choice that society must make--consume the groundwater resource today or save it in the ground for future generations, for a time when climate in the region might not be as favorable to agricultural production as it is today. At which time would that groundwater be of most value? And to whom? Today, other factors have slowed down the rate of drawdown, such as higher energy prices, low crop prices, large stockpiles of grain, and so forth. Nevertheless, the issues of intergenerational equity should be addressed now when there is less pressure to decide one way or another.

Is the Ogallala Aquifer drawdown in fact a national problem? How concerned should national leaders be about the depletion of this regional aquifer? This question hints at the existence of a dilemma. While on the one hand there is interest in generating national concern about the "problem," on the other hand there is a strong desire by those in the region to keep control of the aquifer and its management at the local and state levels. Due in part to the variable thicknesses and longevity of different parts of the aquifer, people in the region prefer local responses to local changes in the aquifer. They do, however, accept the responsibility of the state in the overall management of the aquifer. In fact, a pecking order of preferences emerges from inhabitants of the region: state involvement is preferred over federal and local over state; water conservation measures are preferred over other more drastic changes such as reverting to dryland farming practices.

Societal responses to relatively short-term climatic extremes often spark a search for technological changes on which societies then become dependent. A good example of this would be recurrent droughts in the Great Plains, which ultimately led to a regional dependence on groundwater exploitation from the Ogallala Aquifer for agricultural production.

CLIMATE VARIABILITY AND WATER RESOURCES IN A CALIFORNIA RIVER BASIN

Because of the growth of agricultural production and commercial and industrial development in the Sacramento River Basin, it has become increasingly vulnerable to fluctuations in the magnitude and timing of precipitation. The societal responses to the 1976-77 drought and to flooding in the early 1980s are examined. These responses include changes in the physical structure of resource management systems (such as reservoirs and water transfers), changes in the operation of these systems (such as reservoir rule curves), and a range of socioeconomic alternatives (such as pricing and market mechanisms, institutional initiatives, and regulatory responses).

This study also raises concern about the value of existing information about the frequency and intensity of extreme events, about the magnitude and timing of snowmelt, changes in seasonal evaporation demands, and so on. Water resource planning standards, as we know them today, could become less reliable in the face of a changing climate. Thus, we need a better understanding of climate variability and climate change, including changes in the frequency and range of extreme meteorological events.

Some of the longer-term responses to the mid-1970s drought led to an unintended increase in the vulnerability of the system to high water levels. In particular, changes were made in reservoir operating rules in the late 1970s to increase the ability of the system to provide water under low-flow conditions. These changes worsened the effects of flooding in the early 1980s when unusually high flows occurred.

Like climate, social systems (especially demographic trends) are also changing. As a result, future climate anomalies on the same order of magnitude even in the same locations as past events may have increasingly larger impacts on society and the economy. As demographic patterns change, options that are available today may no longer be useful or even available in the future. For example, in 1976-77, southern California temporarily relinquished its use of a portion of the water normally transferred from northern California. This permitted northern California to use that water to meet its environmental and social demands during the drought. Southern California was willing to do this only because they could make up the difference by temporarily increasing withdrawals of Colorado River water. Yet, in the future the waters of the Colorado River system will be fully appropriated and there will be little chance for surplus.

CLIMATE VARIABILITY AND THE COLORADO RIVER COMPACT

The Colorado River is a highly regulated river that flows primarily through a semi-arid region in which the water demands by society are great, and in which the impacts of climate variability can be major. However, the initial agreement drawn up in 1922, after a few decades of abundant precipitation, to divide the waters of the

Colorado River between the upper and lower basins, essentially ignored the potential effects of climate on the magnitude and timing of river flow. The effects of a "rigid" strategy for dividing the waters of the Colorado and the difficulties of changing such a "rigid" strategy once it was put in place are examined.

Important lessons for the future can be found by reviewing the Colorado River Compact of 1922 and its societal implications. First of all it is unwise to ignore the variability that is inherent in natural systems. Average conditions do not tell the whole story. A mechanism for the periodic rechecking of the rainfall and streamflow data should be built into systems responsible for the long-term management of water resources.

It is important not to ignore changes that will occur in social systems. Even with the same amount of water flowing through the Colorado River system there will be changing needs for and changing values of water resources. This is especially true for multipurpose resources, such as water, where there are constant changes in competing demands.

The decline in streamflow in the Colorado River Basin can be regarded in retrospect as a climate change. We know that the original high estimates of annual streamflow were erroneous, but to date nothing has been done to redress the prospects of shortages which the upper basin states must absorb. There are clear winners and losers in this situation, as a result of reliance on the original overly optimistic estimates.

In retrospect, decisions that bring rigidity to a management system can ultimately generate more problems than they solve. For example, dividing up the water supply in absolute terms as opposed to proportionally has locked the states into certain patterns of interaction. Even though we now know that there is less water in the system today than was originally estimated, and even though there are now clearly identified winners (the lower basin states) and losers (the upper basin states), there is no compelling reason for the "winners" to renegotiate their position.

SEA LEVEL RISE AND COASTAL SUBSIDENCE IN LOUISIANA

Coastal Louisiana is affected by two concurrent problems: sea level rise and coastal subsidence. An important aspect of sea level rise is that multiple impacts are likely to affect different regions in a differential manner, be typically cumulative and generally irreversible. Because the impacts are differential, coalition building becomes difficult and at the same time very important. Federal, state and local responses to coastal land loss and subsidence in Louisiana are examined to evaluate the institutional implications of projected impacts of a sea level rise that has been associated with a global warming.

It appears that those concerned about the implications (political, economic, social, environmental) of wetlands losses, regardless of the causes, agree in general on what needs to be done. What they seem unable to agree on is when and how fast to take action, with some actors wanting to take immediate action and others, feeling a less pressing need to act, wanting to "wait and see" whether environmental changes continue to occur in the future. Nevertheless, at the local and state levels coalitions have formed to deal with the loss of wetlands and marshes.

The coalition that developed in response to wetland losses served to catalyze public demand for action to stop these losses and to strengthen local and state institutional capacity for the management of the wetlands. For example, the state has created a Coastal Protection Trust Fund, with a budget in the tens of millions of dollars. In addition, there is a Coastal Protection Task Force. This case study is a good example of coalition building at the local level in response to local environmental changes.

This case could also serve as an example of how other coastal communities might cope with the societal and environmental implications of a sea level rise (or with coastal erosion or with coastal subsidence or with urban development).

Cumulative impacts will occur over a long period of time and will not occur in a uniform fashion along the coastal areas. This means that there will also be a low probability for the development of a comprehensive strategy to cope with sea level rise on a larger than local (or state) basis, and coalition building on a regional level might be a more difficult process.

CHANGES IN THE MISSISSIPPI RIVER SYSTEM

The Mississippi River is linked to the Gulf of Mexico, Great Lakes, and several other waterways. This navigation system is extremely important for the movement of commodities, such as grain, agricultural chemicals, cement and stone, coal, and petroleum products. It is also widely used for recreation. The system's capacity is directly related to the climate of the entire region. Large changes in water level (too little or too much) can disrupt the flow of trade or at least greatly reduce the efficiency of the system's operation, affecting all parties dependent on commercial navigation. Institutional responses to fluctuations in the river system are investigated.

Most societal actions are, in fact, responses to a given regional stress. Thus, ad hoc reactions occur. Generally speaking, extended periods of extremely low water in the Mississippi River system have not yet been experienced nor have extended periods of excessively high water. Interestingly, we have recently witnessed the period of greatest historical stress, 1959 to 1986; this has been the wettest 28-year period in the climate history of the Mississippi River Basin.

There is really no good long-term analogue in the historic hydrologic record of the Mississippi River system for societal response either to a wetter regime or a drier one. Most responses to hydrologic changes (usually climate induced) in the Mississippi River system have been made in an ad hoc manner in the form of crisis management.

It appears that there is little value placed on drought planning strategies because of the belief that the situation (hydrologic or demographic) will be so different from past situations as to render them useless.

To date, the U.S. Corps of Engineers has worked from existing records and depended for planning on the identification of historical precedents. If the climate is changing, to what extent will the past historical record serve as a reliable guide to the future with regard to large navigational systems? Until we know what a climate change will look like at the regional level, we may not be able to answer that question with a high degree of confidence.

RISE IN THE LEVEL OF THE GREAT SALT LAKE

Utah's Great Salt Lake has risen 12 feet since 1982, flooding valuable lakeshore property and forcing resource managers to address the environmental and societal impacts and the problem of variability in lake levels and climate. Policymakers have been reluctant to address the long-term implications of the problem; instead they have opted to respond incrementally to mitigate impending crises, while hoping that the lake would soon recede and "normal" conditions would prevail.

Because the global warming is likely to be gradual, it is probable that local and regional resource managers will have difficulty in recognizing the initial environmental and societal impacts of a carbon dioxide/trace gases-induced global warming, and thus will respond to these impacts as they have done to other impacts of climate-related environmental stress. Finally, even if decisionmakers recognize that a long-term problem exists, they are still often unwilling to deal with it.

This case study shows that decisionmakers tend to rely on traditional approaches to environmental problems, even when faced with new or unusual conditions. In this particular instance society tended to rely on ad hoc technological fixes and rigid, structural responses that could be completed in the short term. For example, railroad beds were repeatedly raised several feet at great cost each time, as the water level continued to rise. The breaching of the Southern Pacific Railroad causeway was another such response. The final (most recent) and most costly response was the construction of the west desert pumping station at a cost of about $60 million. Even this technological fix exposed the belief of decisionmakers that the water levels of the lake would not rise much beyond its present high stage, because the pumping station would not have been able to cope with inflow on the order of the 1983-86 period.

This study underscores society's tendency to define "normal" in unscientific, often misleading, ways. The considered responses spanned the gamut from adaptive to mitigative to preventive measures. Adaptive measures were favored at first. These were followed by mitigative measures. This study shows that structural responses to climate-related environmental crises can create a false sense of security (e.g., the initial raising of railroad beds or the breaching of the railroad causeway). An additional concern is whether such ad hoc measures tend to build into society a rigidity that precludes optional responses in the face of future climate-related variability.

Hindcasting is considerably easier than forecasting. When assessing responses to climate-related crises we must make sure that we try to recapture "the spirit of the times" so that we do not misinterpret societal responses to past events. Since the west desert pumping station began operations, the lake's level has stabilized (at a high level). Yet, at the time a crisis decision was called for, and the pumping station seemed to be an appropriate response.

CHANGING LEVELS IN THE GREAT LAKES

The Great Lakes Basin's water resources are important to the economic vitality of the American states and Canadian provinces in the region. Recent climatic fluctuations have caused lake levels to deviate significantly from average, thereby affecting commercial shipping companies, hydroelectric utilities, shoreline property owners, and others. Responses of policymakers to past fluctuations are examined to see if they can provide some insights into possible future responses to projected climatic warming.

Many water resource management policies for the Great Lakes have developed in an ad hoc manner, i.e., in response to crises. The lakes oscillate owing to climate variability. Variations in climate are often defined according to local conditions. For example, even during a wet regime (1965-1987), local droughts occurred.

Control measures need to show a greater understanding of how that system oscillates and what the impacts of those oscillations might be and how they may change. This will be especially true because there are demographic changes in the Great Lakes Basin. It has been suggested that if control measures do not reflect the lakes' variability, those measures could exacerbate or amplify the adverse effects of the variability.

It appears that the "struggle" between proponents of ad hoc or long-term responses, operational or structural changes, belief or disbelief in a global warming will continue in the Great Lakes Basin until there is more convincing evidence that there is a dire need for action. Thus, maintaining flexibility is a key element in any policy to cope with future climate-related environmental changes in the region.

With regard to the global warming issue, some scientists suggest that the lake levels should decline rather than rise with a global warming. The rising lake levels and the fact that the 1959-85 annual mean flow (measured at Cornwall, Ontario) is higher than the longer term 1861-1985 mean create confusion among the general public about whether a warming is indeed occurring and whether there is a need for long-term strategy development.

INSTITUTIONAL AND PRIVATE SECTOR RESPONSES TO FLORIDA FREEZES

The Florida citrus processing industry, a major producer of frozen concentrate orange juice (FCOJ), was adversely affected by four freezes in five years in the early 1980s. This set of freezes killed nearly a third of the trees in commercial groves statewide, with much heavier losses in the northern counties. Responses to the social and economic impacts of the freezes by the various levels and institutions of government are examined, as well as responses by the private sector, in order to determine the flexibilities, rigidities, and the general resilience of the system to extreme meteorological events.

This study shows that grove owners are willing to take risks with respect to climate variability. Existing expectations about risk, however, become upset as those risks seemingly increase. It appears that grove owners adjust their risk perceptions in response to climate-related events, perhaps weighting recent events most heavily. Thus, the recent set of freezes has altered their perceptions of the risks that their groves face, as witnessed by their tendency to replace only a portion of their freeze-damaged trees and their desire to develop new groves at the southern edge of the current citrus-producing area. However, the two most recent years without freezes could begin once again to cause grove owners to change their assessment of risk to freezes, thereby causing them to view the set of freezes as anomalous and to view the recent good years as a return to pre-1980 "normal" conditions.

This case study suggests that the most effective and immediate response to a climate-related problem often occurs at the local level and in this particular case through the private sector and not at the state or federal levels. The University of Florida's Institute for Food and Agricultural Sciences (IFAS) seems to have been one of the main public-sector actors in identifying the freeze impacts and suggesting responses to them. Federal disaster programs were not widely used because their goals may have been deemed rigid as well as inappropriate, as they tended to foster replanting citrus groves in the same locations as those decimated in the freezes (a return to the status quo that existed before the 1980s freezes).

While the citrus industry is a large one, it is only a relatively small percentage of the state's economy and perturbations in it have even smaller repercussions for the federal government. Thus, it seems to have essentially remained as a local and state problem, in that order.

Climate anomalies are now on the minds of growers more than before, but in the absence of severe freezes in the next few years, the situation of the early 1980s will fade into history. This situation presents an excellent setting for an assessment of perceptions about climate variability, climate change, and the occurrence of extreme meteorological events.

WATER SHORTAGES IN THE METROPOLITAN NORTHERN VIRGINIA

The use of the case scenario approach in the management of water resources in the Occoquan Reservoir area in northern Virginia is described to see how these methods can be applied to evaluate the potential impacts of extreme water shortages. In such an assessment demographic changes are often as important as changes in climate in assessing the vulnerability of society to climate-related environmental stress.

Lessons from this case study reinforce lessons from other studies; actions to accommodate water resource problems must be taken at the local level; there is usually debate over appropriate actions; and it takes a united front of political and technical leaders to implement a conservation plan.

There is rarely sufficient information available to quantify the risk of dire consequences in a credible manner. In the Occoquan case such information was available and proved to be invaluable in formulating an effective response. The earlier the risk is recognized, the milder the measures required to control it.

It is critical that society continually monitor its vulnerability to changes in climate, and to reassess which measures are most appropriate to reduce that vulnerability. Because the rate of climate change is expected to be small in relation to normal climate variability, society should be able to monitor at least partially its vulnerability to climate change by monitoring its vulnerability to the "normal" variations in climate. An assessment of what constitutes "normal" climate must also continually be updated, based on the most recent meteorologic experiences.

In the Occoquan case it took both a drought and an increase in water use to threaten the reliability of the supply. Societal vulnerabilities change as society changes. The measures appropriate to reduce that vulnerability must also change as both social conditions change and as short-term changes in meteorological conditions occur. Appropriate emergency measures must be thought out and accepted as far in advance as possible to maximize their effectiveness.

CLIMATE CHANGE PERCEPTIONS AMONG NATURAL RESOURCE DECISION-MAKERS:
THE CASE OF WATER SUPPLY MANAGERS

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FINDINGS[1]

Surveys of selected water resource managers show that most are aware of the greenhouse effect and the potential for anthropogenic climate change. Yet most managers do not expect noticeable climatic change in the next few decades and, indeed, tend to expect unusual climatic conditions to return to normal. This expectation, made explicit in resource planning criteria for water and other natural resources, makes sense given the lack of reliable forecasts of long-term climate trends. However, in the face of increasingly credible predictions of anthropogenic climate change, managers may have to override their beliefs about long-term climate stability and yield to the growing logic and public pressure for anticipatory action. Traditional analytical approaches and decision-making approaches in water resource management have the potential to delay or complicate the process of adapting to climate change. Perception studies in other climate-sensitive natural resource management areas are needed to determine their adaptability.

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[1] Although the information in this report has been funded partly by the U.S. Environmental Protection Agency under cooperative assistance agreement number CR-814630, it does not necessarily reflect the Agency's views, and no official endorsement should be inferred.

CHAPTER 1

INTRODUCTION

Research suggests that natural resource planners tend to count on long-term stability or "normality" of environmental variables (Morrisette, 1988; Holling, 1986). This bias appears to be especially strong in water resource planning where long-term future conditions are explicitly assumed to emulate those observed over the past several decades. Statistics describing the central tendency of climatic variables are assumed to exhibit "stationarity" over time, showing no cumulative trends. This assumption pervades essentially all hydroclimatological calculations (Huff and Changnon, 1987; Changnon, 1984; Lettenmaier and Burges, 1978; Riebsame, 1988).

Absent detailed and reliable forecasts of future climate trends, of course, assumptions of climatic stationarity make sense. However, increasingly credible predictions of climate change associated with rising atmospheric concentrations of greenhouse gases due to human activity (see, for example, Schlesinger and Mitchell, 1985; World Meteorological Organization, 1985; Bolin et al., 1986) provide a rationale for analyzing, and perhaps adjusting, expectations of future climate conditions in natural resource planning.

Indeed, managers may soon be forced by the long planning horizons of natural resource systems, and by public pressure, to take preventive or adaptive actions before predictions of climate change become much more detailed, and before incontrovertible evidence for actual climate change emerges. In this ambiguous situation, beliefs and attitudes about climate change are likely to play an important role in how decision-makers respond. Yet little research has been conducted on decision-maker perception of climate (see, for example, Whyte, 1985). The logical first step toward filling this gap is to conduct surveys to discover how managers whose activities are directly affected by climate perceive the emerging issue of anthropogenic climate change. This article describes results of surveys of water resource managers in the southwestern and southeastern United States, and suggests needed research on climate perception.

CHAPTER 2

THE SURVEYS

Three groups of water resource managers were surveyed. First, 32 managers in decision-making positions in California's Sacramento-San Joaquin Valley (with offices in Sacramento) were interviewed as part of a larger case study of water system adjustment to recent climate anomalies (Riebsame, 1988). Next, mail surveys were conducted of water managers in parts of the southwestern and southeastern United States

The California area was selected because it has experienced increased precipitation variability over the last decade. The two mail survey areas were chosen because they exhibit marked precipitation anomalies over the past several years, as identified by Karl and Riebsame (1984). The southwestern U.S. experienced a dramatic increase in annual precipitation since the late-1970s, a trend reflected in greater runoff and rising levels of the Great Salt Lake (see, for example, Phillips and Jordan, 1986; Morrisette, 1988). Arizona's north-central climatic division showed the largest precipitation increase (Figure 1a), but the anomaly also affected most of Arizona, Utah, and Nevada. Parts of the southeastern U.S. have experienced a drying trend over the past several years, especially in terms of summer precipitation (U.S. Army Corps of Engineers, 1988). This is especially evident in the record for North Carolina's southern mountains climatic division (Figure 2a).

Agency and professional association directories, telephone inquiries, and contacts with researchers were used to compile a list of 180 and 80 mail survey recipients in the southwestern and southeastern anomaly areas, respectively. A "snow-ball" approach was used: we stopped adding to the mailing lists as inquiries increasingly yielded repeat names. The goal was not to contact all water resource personnel in each area, but rather to identify those in key decision-making and planning positions. The surveys are thus limited and results may not be widely generalizable to all water managers or to other natural resource managers. Yet, they do plumb the climate perceptions of front-line decision-makers in areas where water resources have recently been stressed by climate fluctuations.

The surveys covered details of local climate, attitudes about climate in resource planning, types of climate-sensitive decisions and operations, and expectations of climate change. Only results related to perceptions of climate change are reported here; a full analysis appears in Riebsame and Cook (1988). Results from the personal interviews in California are presented first; they provided a chance to explore managers' climate perceptions in depth, and offered guidance on the design of the mail questionnaire. Results from the mail surveys of managers in the SW and SE areas are then described, followed by a general summary.

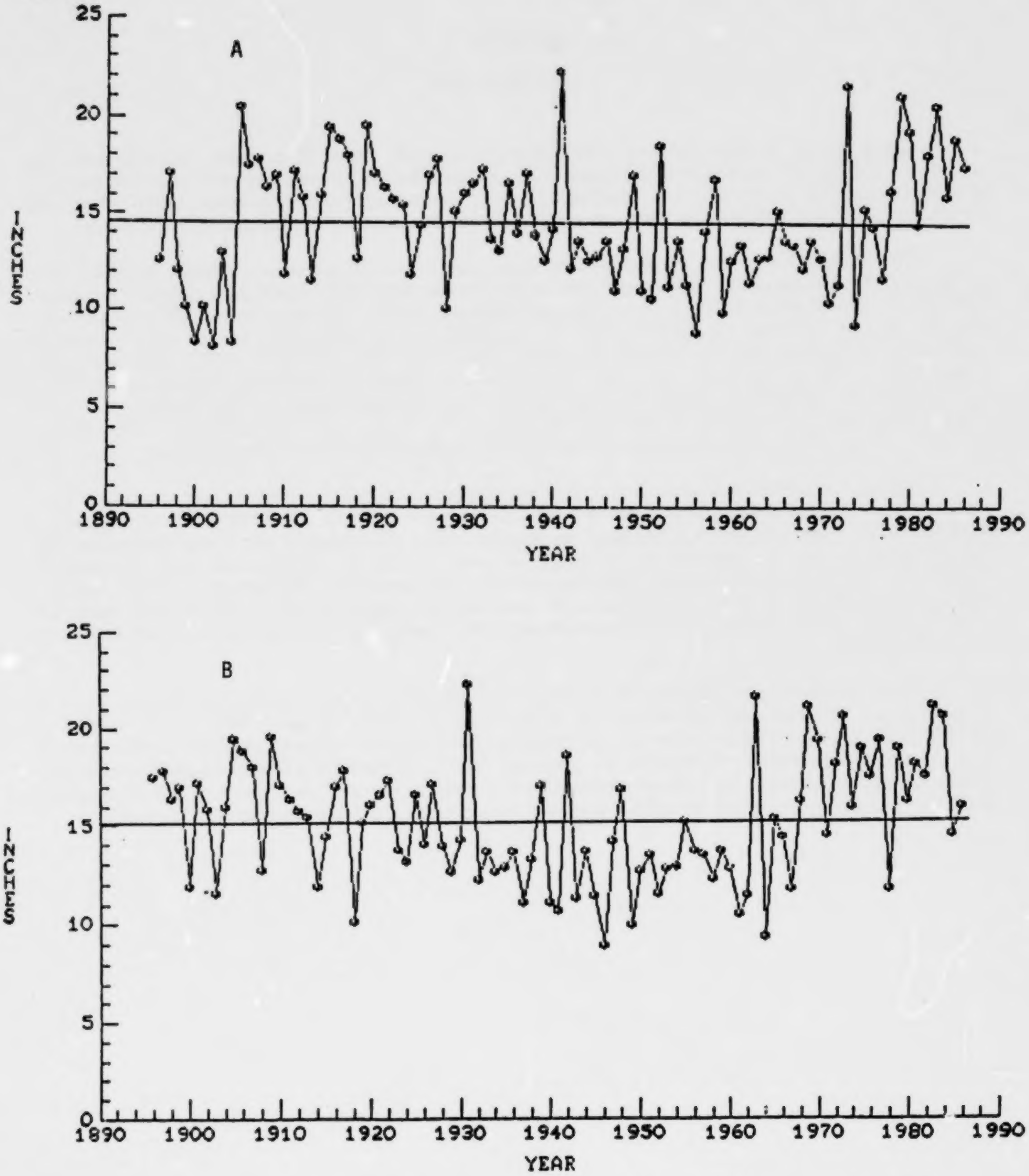
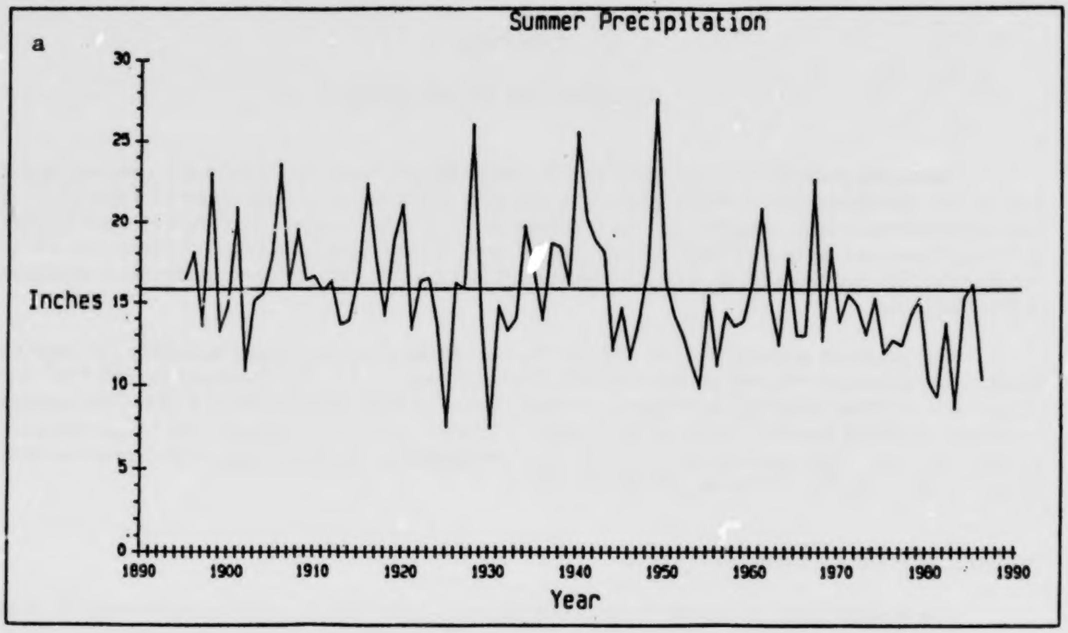


Figure 1. Annual precipitation in Arizona's north-central climatic division: (a) actual record and (b) extended record.



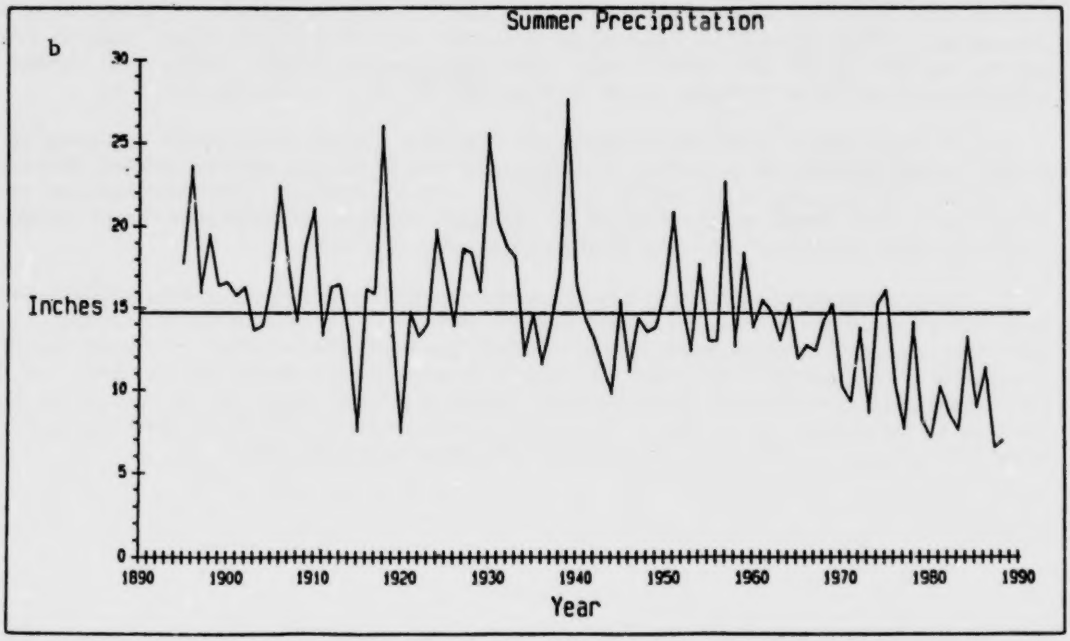


Figure 2. Summer precipitation in North Carolina's southern mountains climatic division: (a) actual record and (b) extended record.

CHAPTER 3

CALIFORNIA INTERVIEWS

Thirty-one professionals associated with the major federal, state, and local water resource agencies in California's Sacramento-San Joaquin Valley with offices in Sacramento were interviewed for this study. These were operations managers, planners, and chief administrators with, for example, the California State Department of Water Resources, Bureau of Reclamation, Army Corps of Engineers, Sacramento County, and the City of Sacramento. We estimate that the interviews included roughly 75% of all first- and second-level administrators of these agencies.

The interview covered several aspects of climate and climate change, including: (1) impacts and adjustments associated with two extreme events in the last 10 years -- the 1986 flood and the 1976-1977 drought; (2) perception of the variability of climate during this 10-year period; (3) perception of 1978-1986 precipitation compared to that of pre-1977; (4) general concepts of climate and climate change; and (5) perception of the greenhouse effect. This paper focuses on respondents' perceptions of climate change, with emphasis on potential climate changes associated with the greenhouse effect.

PERCEPTION OF CLIMATE CHANGE

Ninety percent (28) of the interviewees said they were informed about the greenhouse effect. Fifty-two percent (16) of the water managers we interviewed believe that the climate of the earth is changing, and half of these cited the greenhouse effect as the cause. There was, however, no consensus among respondents on precisely what about the earth's climate is changing (e.g., precipitation patterns, variability, or seasonal characteristics). When asked if the climate of the Sacramento area was changing, 55% (17) said no, 26% (8) said yes, and 19% (6) felt that it exhibits cycles rather than permanent changes. When asked whether they expected the area's climate to change in their lifetimes, 76% (19 out of 26 respondents) said no.

Similarly, 79% (19 of 25[2]) do not believe that their water resource agency should be planning for the possible impacts of future climate change. It was generally thought that regional water resource planning for a greenhouse climate change is not justified until there is better documentation of the probability and severity of potential impacts. However, all but one of the respondents thought that greenhouse climate change, if it does occur, would be harmful rather than helpful to humankind as a whole.

Respondents were then asked to assume that climatologists had provided a credible projection that the area's climate would be 1 to 2 degrees warmer and 10% drier (or wetter) over the next few decades and then asked how probable the scenario would have to be before they would advocate efforts to plan for the change. Five people (17%) said they would wait for evidence of actual climate change and its effects, and three interviewees said they would need detailed information about the potential impacts before they could answer the question. Of the 21 people who answered the question with a percentage, 18 (86%) indicated that the scenario would have to be at least 50% certain and 9 (43%) answered at least 75% certain.

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[2] Note that sample size varies between questions; respondents were free not to answer all questions. The number answering a question is provided when it is different than the full samples: California (31), the Southwest (76), and the Southeast (42).

PERCEPTION OF INCREASED CLIMATE VARIABILITY AS AN INDICATOR OF CLIMATE CHANGE

Precipitation in the Sacramento-San Joaquin Basin exhibited a marked increase in interannual variability during the mid-1970s, and large year-to-year variability has continued to the present (Figure 3; see also Riebsame, 1988). This enhanced variability is highlighted by the 1976-77 drought and 1986 floods, events which dramatically extended the historical range of Basin precipitation and runoff. All the interviewees were aware of the statistical rarity of both the drought and flood, and 25% (7) interpreted events of the past 10 years as a shift toward increased precipitation variability. Yet, 68% (19) either referred to the recent variability a freak period which would not recur or claimed that it was not so unusual, referring to the area's reputation for highly variable seasonal and annual precipitation. There was great reluctance to use words like "climate change" or "trend" to describe the recent spell of large variability.

When those who felt that the area's climate was changing (eight respondents to an earlier question) were asked how it is changing, no one mentioned an increase in precipitation variability, though five mentioned increased rain (amount or frequency) or flooding, one mentioned increased drought, and several mentioned changes in seasonality.

Interviewees were then presented a graph of precipitation for the area from 1945 to 1986 (Figure 3) and asked how many more years the heightened variability would have to be sustained before it could be considered a change in basic climatic patterns. Only one of the respondents believed that this period already constitutes a basic change in climate. Seven (27%) of the respondents said the pattern would need to be sustained for an additional 10 to 20 years, and six (23%) wanted to see an additional 20 to 100 years of variability, before they would consider the basic climate patterns changed and would begin planning for a different set of climate conditions. Six respondents believed that the question could not be answered because either the instrumental record was not long enough or there was no good rule for interpreting the data to determine whether climate change was under way or had occurred.

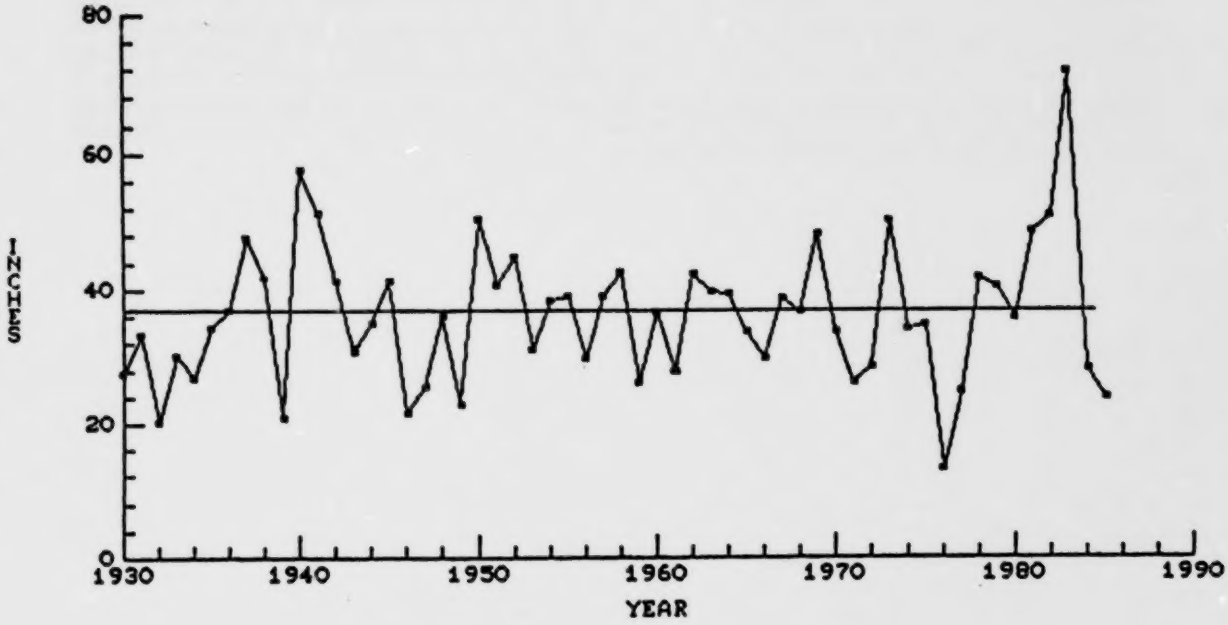

Figure 3. Sacramento Basin annual precipitation.

CHAPTER 4

RESULTS OF THE SOUTHWESTERN AND SOUTHEASTERN MAIL SURVEYS

Results from the two mail surveys are described jointly. Not all of the questions used in the California interviews were repeated in the mail surveys, although many similar questions were asked in formats more appropriate to a mail questionnaire.

PERCEPTIONS OF CLIMATE CHANGE

Seventy-six and 42 questionnaires were returned from the southwestern and southeastern surveys, respectively. All but a few of the water managers surveyed had heard of the greenhouse effect, but they tended to assign low probabilities to future global or local climate change. We asked managers to assign probabilities to the potential, over the next 30 years, for global climate change (defined as at least a 1 degree C. global warming), noticeable local climate change, and the need to change water management practices because of climate change.

The distribution of responses in 10% increments is shown in Tables 1 and 2. Sixty-seven percent (48) of the respondents in the southwest assign less than a 50% chance of global or local climate change in the next three decades. In the southeast sample, 58% (22) of the managers give less than a 50% chance of global climate change in the next 30 years, and 71% (27) feel that the chance of noticeable local climate changes over the same period is less than 50%. Seventy-five percent of the southwestern managers and 71% of the southeastern managers assignless than a 50% chance of having to change water resource practices over the next three decades because of climate change.

Yet 35% (26) of the southwestern water managers felt that the area's climate was changing, and 52% (23) of the southeastern water managers felt that their climate was currently changing.

PERCEPTIONS OF RECENT CLIMATE TRENDS AS INDICATORS OF CLIMATE CHANGE

The mail survey recipients were given two climate graphs. The first showed actual precipitation amounts for the climatic divisions used as anchors in this study (Figures 1a and 2a); these were labeled only as "precipitation records in your area." Next, the two records were extended using a simple rubric: the trends that initially attracted our interest (recent runs of wet and dry years in the southwestern and southeastern areas, respectively) were extrapolated for a decade at roughly the same rate with similar variability (Figures 1b and 2b).

Managers were then asked whether the recent periods were "consistent" or "inconsistent" with the longer record for both the actual and the extended records, and whether "new climatic regimes" were being established. They were also asked to predict the precipitation trend over the next decade.

As shown in Table 3, most of the southwestern respondents felt that the recent record was "consistent" with the long-term record in both the actual and extended records (73 and 58%, respectively). Yet, only half of those who labeled the recent years as "inconsistent" with the longer-term records in both the actual and extended records felt that a "new climate regime" was being established. Most (75%) felt that the historical record was too short to determine whether "climate change" was occurring.

TABLE 1
PERCEIVED LIKELIHOOD OF GREENHOUSE CLIMATE CHANGE: SOUTHWESTERN WATER MANAGERS

Likelihood	>1°C Global Warming[a]		Local Change[b]		Mgmt. Change[c]	
(%)	Cum Fq	Cum %	Cum Fq	Cum %	Cum Fq	Cum %
0	3	4.3	3	4.3	6	8.7
1-10	12	17.1	16	23.2	22	31.9
11-20	22	31.4	25	36.2	35	50.7
21-30	34	48.6	35	50.7	44	63.8
31-40	40	57.1	40	58.0	48	69.6
41-50	50	71.4	51	73.9	58	84.1
51-60	57	81.4	59	85.5	60	87.0
61-70	62	88.6	61	88.4	64	92.8
71-80	67	95.7	66	95.7	66	95.7
81-90	69	98.6	69	100.0	68	98.6
91-100	70	100.0	0	100.0	1	100.0
	n=70		n=69		n=69	

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[a] How likely is it that the average temperature of the earth will rise at least 1'C in the next 30 years due to the greenhouse effect.

[b] How likely is it that the climate of your area will change noticeably within the next 30 years?

[c] How likely is it that water resources management practices in your area will be forced to change due to climate change in your area will be forced to change due to the climate change in the next 30 years?

TABLE 2
PERCEIVED LIKELIHOOD OF GREENHOUSE CLIMATE CHANGE: SOUTHEASTERN WATER MANAGERS[a]

Likelihood (%)	>1 C Global Warming		Local Change		Mgmt. Change	
	Cum Fq	Cum %	Cum Fq	Cum %	Cum Fq	Cum %
0	2	5.3	2	5.3	3	7.9
1-10	5	13.2	9	23.7	7	18.4
11-20	9	23.7	9	23.7	11	28.9
21-30	14	36.8	13	34.2	16	42.1
31-40	19	50.0	21	55.3	22	57.9
41-50	22	57.9	27	71.1	27	71.1
51-60	24	63.2	29	76.3	29	76.3
61-70	31	81.6	32	84.2	32	84.2
71-80	37	97.4	37	97.4	34	89.5
81-90	1	100.0	38	100.0	35	92.1
91-100	0	100.0	0	100.0	38	100.0
	n=38		n=38		n=38	

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[a] Questions same as table 1

TABLE 3

PERCEPTIONS OF CLIMATE RECORDS

	Actual SW Record		Extended SW Record	
	Freq	%	Freq	%
Consistent[a]	54	73	41	54
Inconsistent[b]	20	27	30	46
New Precipitation Regime?[c]	11	51	14	49
	Actual SE Record		**Extended SE Record**	
	Freq	%	Freq	%
Consistent[a]	16	40	16	39
Inconsistent[b]	24	60	25	61
New Precipitation Regime?[c]	18	75	24	96

[a] Is the last decade's precipitation record consistent or inconsistent with the long-term precipitation regime?

[b] Is the precipitation record of the last two decades consistent or inconsistent with the long-term precipitation regime?

[c] Those who answered that the recent period was inconsistent with the long-term record were then asked whether a "new precipitation regime" was being established.

In contrast, slight majorities of the southeastern managers felt that the recent spell of drier conditions was "inconsistent" with the previous climate for both the actual and extended records (60 and 61%, respectively), and most of those applying the term "inconsistent" felt that a new climate regime was being established.

It is important to note that while the southwestern survey was conducted in the fall of 1987, the southeastern survey was conducted during the late-spring of 1988 and that some questionnaires were not returned until late in the summer of 1988. The summer was marked by dramatic heat and drought in the southeast and elsewhere and was a period in which the greenhouse effect became a common element of public and professional discourse about the climate. Still, only half of the southeastern managers surveyed, and less than a fifth of the southwestern managers, were willing to characterize recent climate anomalies, even those extended a decade beyond the actual record, as the emergence of a new climatic regime (Table 3).

FUTURE EXPECTATIONS

Like the California water managers, the mail survey respondents tended to expect future conditions to "return to normal" or compensate for the unusual conditions of recent years (Table 4). However, the southeastern group was more evenly divided between expecting the drying trend to return to normal or to continue. Again, perhaps the heightened climate change awareness during the summer of 1988 made southeastern water managers more open to the possibility that the recent trend would continue and that it might even be a fundamental climate change rather than an anomaly destined to return to normal.

TABLE 4
EXPECTATIONS OF FUTURE CLIMATE[a]

Expectations	Actual SW Record		Extended SW Record	
	Freq	%	Freq	%
Return to average	42	58	41	58
Continue wetter	16	22	15	21
Swing to drier	15	20	15	21
	n-73		n-71	
	Actual SE Record		Extended SW Record	
	Freq	%	Freq	%
Return to average	18	47	19	49
Continue drier	16	42	15	46
Swing to wetter	4	01	2	05
	n-38		n-39	

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[a] What is the most likely trend in the precipitation record over the next decade?

CHAPTER 5

SUMMARY

Overall, the water resource managers surveyed in this study are cognizant of the greenhouse effect and potential near-future climate change. However, their expectations of climate change are ambivalent. While half of the managers interviewed in California felt that the earth's climate was changing, most do not feel that their local climate is changing and few expect to experience climate change in their area over the next several decades. Most felt that they should not be planning for climate change. Though they recognize that the area's climate has been more variable lately, only one was willing to characterize the recent period of heightened precipitation variability as a climate change, and most said that the pattern would have to continue at least another 10 years before they would consider factoring the new conditions into long-term plans.

Water managers in the southwestern and southeastern mail surveys tended to assign low probabilities to the potential for noticeable global or local climate change over the next three decades. They generally do not expect climate changes sufficient to require altered water resource system planning or operation in the foreseeable future.

The water managers avoided terms like "climate change" or "new climate regime" in characterizing unusual conditions or trends. Most of the southwestern managers would not characterize the recent wet spell as inconsistent with past conditions, nor would most identify it as a new climatic regime, even when it was extrapolated 10 years into the future. They tended to expect the recent wet pattern to return to average in the next several years. Southeastern water managers were slightly more likely than southwestern managers to identify recent precipitation trends as inconsistent with past conditions, and most of those felt that it did contitute a "new climate regime." Nevertheless, a small majority expected the drying trend to revert to average.

A stronger bias shows up in responses to the question of whether the roughly 100-year-long records presented to the managers were sufficiently long for them to determine whether the climate was changing. Most said no (75% in the Southwest and 71% in the Southeast). Managers appear to be focusing on very long, perhaps geologic, time scales when they think of climatic change, despite the emerging scientific consensus that significant and rapid change may be forced by an enhanced greenhouse effect over the next several decades.

CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

The survey results reported here suggest that water managers are ambivalent about the potential for climate change in the near future, that they do not expect climate change to force changes in water management practices in the foreseeable future, and that they exhibit, at least weakly, what some researchers have called a "normality bias" in their anticipations of future climate conditions. Most of those surveyed in this study do not believe that the climate is changing or will change in the next several decades. Even a majority of the southeastern survey respondents, half of whom feel that the region's climate is "changing," assigned less than a 50% chance of noticeable local climate change due to the greenhouse effect over the next three decades.

When presented with evidence of unusual climate conditions in their area, most managers tended to deny the possibility of fundamental climate change, to refer to recent anomalies as temporary fluctuations, to expect future conditions to revert to more average conditions, or to deny that climate change could be determined from a 100-year climate record.

Of course, in the absence of reliable predictions of climate trends, expectations of stationarity make sense. However, projections of fundamental climate change due to the greenhouse effect are becoming increasingly credible, and anthropogenic climate change has several unique characteristics that fit poorly with managers' perceptions and biases. First, it is predictable at least in terms of general trends if not local details or magnitudes of change. Second, trends that emerge from climatic noise due to the greenhouse effect are likely to be cumulative rather than tending to return to pre-existing average conditions -- unless, of course, the infusion of greenhouse gases is reversed. Third, the marked increase in greenhouse gas concentrations in the atmosphere over especially the last several decades means, simply, that the more recent segments of existing climate records may more accurately reflect the current and near-future climate than do earlier data. Yet, water managers tend to weigh whole historical records evenly and, as shown in this study, feel that fluctuations must endure several decades before they can be considered permanent trends.

Resource managers will have to override some of their traditional expectations and biases in order to adjust to anthropogenic climate change. This is true whether they adjust in the face of actual evidence for change, or if public pressure to anticipate predicted changes becomes stronger. They will have to adopt new ways of assessing climate records that eschew assumptions of stationarity and develop management criteria sensitive to secular climate trends.

The findings presented here may indicate some of the management problems that will be encountered as decision-makers respond to climate change or predictions of climate change. First and foremost, there is great ambiguity as to what constitutes a climate change, and managers disagree on what magnitude of change is needed to require some overt response. Managers are also divided in their beliefs about climate stability and change.

The evidence here suggests that the greenhouse effect as it is currently perceived by decision-makers is too uncertain and/or poorly defined to provoke overt response. Nevertheless, scientists' concerns and news media coverage may eventually evoke a public mandate for preventive action. Thus, it appears that scientists studying climate change, and policy-makers considering human response, face a large educational task. As climate research creates improved records of global change and yields more credible forecasts of future changes, it is essential that the information be communicated in a meaningful and useful fashion to professional resource managers in the most sensitive sectors. This step is easily neglected, or it is assumed to follow automatically from progress in the physical science. But we know very little about how to communicate information on large-scale, sometimes subtle and cumulative, environmental changes that may lie below the perceptual thresholds of most resource managers.

The ambiguity with which resource managers now perceive climate change issues should be carefully noted by scientists and policy-makers who are more convinced that climate change poses a threat. Without better communication of this threat they are likely to be dissatisfied with resource manager response, even in the most climate-sensitive areas like water supply management: resource managers may be slow to respond to information on climate change, and may delay adjusting water systems until well after significant climate changes and impacts have occurred.

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APPLICABILITY OF FEDERAL LONG-RANGE PLANNING AND ENVIRONMENTAL IMPACT STATEMENT PROCESSES TO GLOBAL CLIMATE CHANGE ISSUES

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CONCLUSIONS

- Federal agencies are making long-range decisions concerning agriculture, forestry, water resources, coastal zone resources, and energy resources with little or no regard for long-range climate impacts. This is particularly true for actions potentially affecting climate, such as national energy plans, federal energy programs that are not analyzed in EISs, and specific energy projects that are subjects of EISs. It is also true for long-range plans and EISs concerning national forests, navigable waters, and coastal resources that may be affected by climate change. Federal projects, funds, and licenses for infrastructure development lasting 50 years or more are planned, assessed in EISs, and implemented under the assumption that present climate conditions will prevail.

- EISs on long-term federal actions can help federal decision makers and the public understand how global climate may affect, or be affected by, the proposed actions or reasonable alternatives without changes in NEPA or the EIS procedures. The EIS process is widely understood by agencies and the public, and it facilitates public participation and agency coordination at all levels. If strong and continuous efforts are made to adhere to existing NEPA regulations and to prepare readable, accurate, and well-focused EISs, these documents can raise the level of public understanding of global climate change by disclosing possible long-term costs of various options. Greater use of programmatic, generic, and regional EISs can overcome limitations of project-specific analyses by focusing on cumulative impacts and alternative approaches and technologies. EISs can refer to and complement other agency studies that may be necessary, and sometimes more appropriate, to address climate impacts and effects.

- The most immediate practical step in improving climate impact assessment is to use EISs to identify on a comprehensive basis the resources that are most sensitive to climate warming and drier or wetter conditions and/or sea level rise. EISs concerned with climate impacts must focus on the needs of decision makers, and agencies have limited time and money for EIS preparation. Agencies must rely on and incorporate existing information on climate change scenarios into their EISs.

- Several existing long-range planning and EIS processes can incorporate climate change and environmental impact scenarios.

    - The Forest Service Assessment and Program requirements of the Resource Planning Act and the forest unit planning process offer the most comprehensive opportunity for national forest and range resources.

    - Public land planning processes of Fish and Wildlife Service, National Park Service, and Bureau of Land Management, offer possibilities to integrate climate scenarios and sensitivity analyses into national and unit plans and operational decisions.

    - States can address potential impacts of sea level rise under their approved Coastal Zone Management plans and thereby help shape federal actions and EISs concerning specific geographical areas.

    - Corps of Engineers regulatory permit programs have supported areawide local planning that can also incorporate climate change scenarios. Many other site-specific EIS processes concerning coastal construction, infrastructure, and resource protection can address the long-term effects of sea level rise on development decisions directly or indirectly caused by the proposed action or its alternatives.

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[1] Although the information in this report has been funded wholly or partly by the U.S. Environmental Protection Agency under Contract No. 68-03-3533, it does not necessarily reflect the Agency's views, and no official endorsement should be inferred from it.

- Significant gaps exist in agency long-range planning and EIS processes related to actions that may contribute to climate change impacts and to actions potentially affected by climate change.

  - No comprehensive long-range planning/EIS process addresses the effects of, and alternatives to, federal actions affecting the emission of greenhouse gases. Energy-related EISs are largely limited to site-specific actions because the National Energy Plan has not addressed these issues and it has not been subject to EIS requirements. Program EISs have been prepared on coal leasing on public lands, oil leasing on the outer continental shelf, and aspects of nuclear power, but they have not addressed climate impacts. Moreover, no comprehensive long-range energy plan/EIS examines the cumulative emission effects of energy production and use on climate.

  - On the other side of the equation, no comprehensive federal river-basin planning and decision process exists to address climate-related effects on federal water resource projects or private permit proposals. As a result federal agencies have a limited ability to apply EISs to climate impacts on water resources on a broad geographic scale for all parts of the United States.

RECOMMENDATIONS

- Federal agencies should have guidance on the climate change scenarios they should consider for different kinds of actions subject to EISs, including what information is available, and where, for particular regions. Guidance should include ways in which agencies should assess the impacts of present assumptions about climate stability and the sensitivity of various environmental conditions to climate changes. The Council on Environmental Quality has provided this kind of guidance on other topics, often with the assistance of EPA and other agencies. It is appropriate for the Council to provide guidance to federal agencies on climate change data and analysis that can be practically applied in different kinds of EISs.

- Agency experiences in applying climate data in EISs should be regularly shared among agency EIS staff to help them learn from past successes and problems. The Council on Environmental Quality, in cooperation with EPA and other appropriate agencies, could play an important role in distilling and distributing such information. Information should be developed as part of a rigorous, comprehensive review by the Council of federal agency compliance with existing NEPA regulations.

- Significant gaps in long-range planning, decision making, and EIS requirements need to be filled to give government agencies and the public better opportunities to understand and affect significant global climate issues. One possible step in that direction would be to require that the global climate effects of federal energy policies, programs, and regulations be addressed in long-range plans that are subject to EIS requirements. EPA, in cooperation with the Department of Energy, should assess the opportunities to improve long-range planning and impact analysis of energy program regulations affecting the emission of greenhouse gases and research activities in terms of their potential climatic effects. Even where EISs are not required for significant actions causing greenhouse gas emissions, consideration should be given to climate impact analyses in EPA's "functional equivalent" EISs or in other documents.

CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE OF REPORT

This report assesses whether and how the environmental impact statement (EIS) process required by the National Environmental Policy Act can be used to address long-term impacts related to global climate change. When appropriating funds for Fiscal Year 1987, Congress asked the Environmental Protection Agency to report on the "feasibility of utilizing the EIS process to ensure that climate change is considered in long-range development projects." As discussed in Chapter 2, many federal agencies carry out actions that may affect, or be affected by, global climate change. These actions frequently require EISs, although many other actions with important relationships to climate change are not subject to EIS requirements. To help EPA give a practical answer to Congress' question concerning the opportunities and limitations of EISs on climate relationships, Chapter 3 of the report examines planning and EIS capabilities of several federal agencies and how they relate to global climate change. Because sea level rise is one of the clearest effects of global climate warming, Chapter 3 also examines other federal planning and EIS processes concerned with the coastal zone.

1.2 BACKGROUND ON THE NATIONAL ENVIRONMENTAL POLICY ACT BASIC REQUIREMENTS

The National Environmental Policy Act (NEPA) of 1969 requires environmental impact statements for "major Federal actions significantly affecting the quality of the human environment." Actions subject to this requirement include proposed programs, plans, regulations, and recommendations for legislation by federal agencies such as the Federal Energy Regulatory Commission, the Environmental Protection Agency, Forest Service, and Corps of Engineers. Impact statements on these proposals are intended to affect the decision making process by analyzing any significant direct, indirect, and cumulative impacts of the proposed action and reasonable alternatives.

The Council on Environmental Quality's NEPA regulations of 1978 clarify the purpose and focus of EISs and the procedures that agencies must follow to meet NEPA requirements.

EIS review responsibilities. NEPA requires all federal agencies to review and comment on EISs concerning matters within their jurisdiction and expertise. In addition, §309 of the Clean Air Act requires EPA to review EISs for actions that might affect any of EPA's statutory responsibilities. Proposed actions that EPA believes would be "unsatisfactory from the standpoint of public health, or welfare, or environmental quality" may be referred to the Council on Environmental Quality.

EIS limitations. Limitations of the EIS process can affect the feasibility of using EISs to conduct practical global climate impact analysis. EISs are required only for new federal proposed actions, not existing actions. The actions must be federal, and not private, and minimal federal involvement in a private action may not "federalize" an action for NEPA purposes. Actions must also be proposed for implementation, and not simply contemplated or studied. Hence, EISs may not be required for important plans or studies if they are not considered "proposals" by a federal agency under NEPA. Instead, EISs may only be required at the project level, for a specific federal action on a highway, water resource project, or a permit for a coal/oil power plant or hydroelectric dam, for example. The cumulative impacts of each project on, or from, climate change, may, in some cases, be analyzed in a comprehensive programmatic, generic, or regional EIS is any agency carries out a larger plan or program. As discussed in this report, such comprehensive EISs are required for many federal actions that may be significantly affected by climate change. Far fewer requirements exist for comprehensive EISs concerned with impacts on climate in the absence of agency mandates to prepare, for example, a national energy program, or a regional transportation plan.

Congress has explicitly excluded some agency actions from EIS requirements and therefore these are not examined for EIS feasibility in this report. Notable among these exclusions are EPA's regulatory actions under the Clean Air Act concerning emissions that may affect global climate.

Other EIS limitations are also important. Many basic agency decisions are not embraced by EISs under NEPA, such as budget requests to the Congress. For practical reasons, agencies focus on the most measurable, clearly documented impacts, and have limited time, resources, and inclination to address long-term, speculative impacts. EISs are required to address cumulative impacts, but the analysis is often difficult and their response has often been weak.

1.3 LONG-RANGE PLANNING BY FEDERAL AGENCIES

Whether the EIS process can effectively address global climate impacts depends on the long-range decisions an agency makes and how EIS requirements apply. Requirements for long-range planning by federal agencies are eclectic and often limited. Experience with federal actions that affect global climate are limited; EIS-like planning documents are especially rare. The Department of Energy prepares a biennial national energy plan with no EIS or consideration of climate impacts. Most experience and the clearest requirements concern actions likely to be affected by climate change. The Forest Service, for example, has an elaborate, congressionally required long-range forest planning process integrated with EISs; national or river basin plans are no longer required for federal water resource agencies since the abolition of the U.S. Water Resources Council, but the Corps of Engineers conducts plans and EISs for water projects and some areawide EISs for private permits affecting United States waters.

In the coastal zone, states establish plans and programs under the Coastal Zone Management Act, and federal approval requires an EIS. Coastal development projects that fall within the Corps of Engineers regulatory permit program, and projects located in the coastal zone, such as highways and airports (Department of Transportation), and sewage treatment plants (EPA), are subject to environmental assessments or EISs. They must be consistent with the federally approved coastal zone management plan.

Federal agencies carry out assessments and planning that do not require EISs, but these activities may affect subsequent agency actions that do. The Department of Agriculture's appraisal of soil, water, and related resources and trends on private lands does not require an EIS, but its data are reflected in project level actions and EISs of the Department.

Many other federal actions may directly or indirectly affect energy use and global climate, including agricultural subsidies and federal procurement policies, but they have not been subject to long-range planning and EIS requirements.

International programs of the Agency for International Development (AID) often affect natural resources, coastal zone conservation, and energy use and conservation. EISs are rare, but AID often prepares impact assessments on AID projects. AID's project planning and approval documents may also address long-term environmental impacts of program commitments.

1.4 STUDY APPROACH

An underlying hypothesis of this study has been that EISs can be an important element in federal responses to climate change issues given that they address the dominant causative agents as well as the mitigative agents. Because EISs are intended to help decision makers and the public anticipate environmental problems, existing planning and EIS processes should, presumably, help them assess impacts on, and effects from, global warming.

To examine the feasibility of EIS consideration of global climate issues the study identified the range of federal actions subject to NEPA that were reasonably related to climate effects. Included were plans, programs, regulatory actions, and projects concerning energy use and greenhouse gas emissions affecting global change and actions affected by climate change. Because of the need to assess practical opportunities for, and barriers to, the application of existing long-range planning/EIS processes to global climate change the study focused on agencies having the most experience with long-range planning and EISs. For reasons noted above and discussed below, the agencies selected are those whose actions concern impacts from, rather than on, global climate change.

CHAPTER 2

FEDERAL ACTIVITIES WITH POTENTIALLY SIGNIFICANT RELATIONSHIPS TO LONG-TERM GLOBAL CLIMATE CHANGE

This section briefly describes the federal policies, programs, plans, regulations, and projects that have a potential effect on global climate change or which may be affected by such change. Actions and responsibilities are included if they might increase $C0_2$ and other greenhouse gas emissions into the upper atmosphere, or may be affected by sea level rise or changes in temperature, rainfall, and the water cycle. The Appendix supplements this discussion by listing specific federal programs that are reasonably related to global climate change.

2.1 FEDERAL ACTIVITIES RELATED TO GLOBAL CLIMATE CHANGE

2.1.1 Federal Energy Programs

Energy conservation programs of all kinds have direct relationships to activities that contribute to global climate change. Although the Department of Energy's conservation programs are divided into separate elements, they could be considered in the aggregate to assess their climatic effects. Policies affecting the mix of fossil fuels used are also important. Federal policies that encourage the use of coal but discourage the use of natural gas can contribute to the greenhouse problem; coal combustion, unlike natural gas combustion, releases nitrous oxide.

The regional energy programs of the Bonneville Power Administration and the Tennessee Valley Authority are important because they affect the basic energy use and conservation practices of entire regions.

Basic energy production research into high energy and nuclear physics, magnetic fusion energy, hydrogen fuel, and other technologies are climate-related because they concern alternatives to fossil fuel. Research and development of these technologies could be addressed comprehensively to assess their long-term climate impacts.

EPA's air quality regulatory programs, although exempt from EIS requirements, may have important impacts on energy use and the emission of greenhouse gases.

2.1.2 Agricultural Programs

Global warming that could make the Midwest warmer and therefore drier, coupled with continued competition for water for urban use, would affect federal agriculture commodity programs by reducing or increasing supplies of wheat, corn, and other subsidized crops. Farm loan programs may be affected by climate impacts on the economic health of farm families and enterprises.

Research programs of the Department of Agriculture could be affected by climate change and could be important in helping to evaluate climate change effects. Examples include the Cooperative State Research Service program for grants to land-grant colleges and universities, research programs of the Forest Service, and the Soil Conservation Service's Plant Materials for Conservation program.

Changes in crop conditions in the West and Midwest may affect agricultural conservation and commodity programs. Soil and Water Conservation Service programs in the Great Plains and western states may be affected if increased drought exacerbates soil erosion. The same amount of conservation may require considerably more funds for the same result under some global warming conditions. On the other hand, commodity support programs can cost less if farmers produce less. Different costs and savings would result if western rainfall increases, as some climate scenarios suggest.

2.1.3 Public Lands and Wildlife Programs

Land use decisions of federal agencies, including the Departments of the Interior, Agriculture, and Defense may be affected by climate changes that reduce rainfall and surface and groundwater resources. Increasingly dry conditions in the West would affect forestry, reclamation, wildlife management, and many other programs on and off public lands.

Priorities for acquisition of lands for federal agencies under the Land and Water Conservation Fund may be affected by climate change as federal agencies identify lands that may become more or less valuable for recreation or protection. Potential impacts of climate change on endangered species habitat or migratory waterfowl may be significant. Climate change may also affect priorities for better protection of ecosystems through acquisition of easements, private in-holdings in public lands, and private lands outside existing boundaries.

Most Interior Department activities on public land are project-specific, although park, refuge, and land resource and range management programs can be important too. The project-specific actions on mines, transmission lines, pipelines, and roads may be affected by climate change--through changes in precipitation, wildlife habitat, reclamation potential--but they are not easily analyzed in terms of climate sensitivities.

2.1.4 Coastal Programs

Sea level rise is among the most certain effects of global climate warming, and coastal programs will have the most predictable impacts. If sea level were to rise approximately 1 meter by the middle of the 21st century, most coastal wetlands would be inundated and lost if upland development leaves no room for them to "migrate." Existing shores of barrier islands and beaches will retreat. Present settlements will be flooded.

Many sewage treatment facilities, highways, railroads, waterfront developments, ports, and other facilities constructed, funded, or licensed by federal agencies may be directly affected by coastal floods, erosion, salt water intrusion, or higher water tables. Developments induced by this infrastructure in the coastal zone may also be affected, including houses, condominiums, and businesses.

Coastal wetlands, parks, recreation areas, and urban developments are all affected by many federal actions. These include navigation improvements; harbor dredging; small stream channelization; impoundments for flood control; coastal erosion control projects; sewage treatment facilities; highway and airport construction and expansion; permits for industrial, commercial, and recreational projects; onshore oil and gas facilities and pipelines, and bridges; and federal mortgage guarantees for housing developments. Major agencies involved in these programs are the Departments of Transportation, Housing and Urban Development, Interior, Commerce, and EPA. The Corps of Engineers affects coastal wetlands through its own water resource projects and by regulating dredge and fill actions of private parties. Federal agencies with jurisdiction and expertise, such as EPA and the Fish and Wildlife Service, routinely review and comment on EISs affecting coastal wetlands.

2.1.5 Inland Water Resource Programs

Wetland protection programs of all agencies may be affected by climate change. Reductions or increases in rainfall in parts of the country will affect the numbers and size of many types of wetlands. Changes in inundation or saturation patterns would alter soil and vegetation conditions. Warmer temperatures may create drier conditions despite greater rainfall. Areas now defined as wetlands may not qualify as wetlands in the future. Federal programs under §404, the "Swampbuster" program, and many others, may be directly affected.

Water resource development programs and priorities may be substantially affected by climate change that affects rainfall, surface and ground water, but precisely what these effects may be is unclear. Projects for water conservation, irrigation drainage, and cleanup of contaminated wetlands may all be affected by global warming, as may navigation improvement and maintenance programs.

The National Wild and Scenic Rivers Program, managed by the National Park Service and the U.S. Forest Service, was designed to protect the values of significant free-flowing rivers and streams in the U.S. Since 1968 more than 7,000 miles of river have been added to the system, protected from federally supported or licensed water resource management activities. Priorities for protection may need to respond to changes in regional water cycles, stream flows, and other hydrologic conditions.

2.1.6 Federal Construction

Federal grants for construction of highway systems by the states constitute the largest single federal construction expenditure--about $13 billion in FY 87. Airport construction assistance, nearly $1 billion in FY 87, is another important item. Environmental groups have often criticized both programs for their encouragement of fossil fuel use. These and other federal construction actions may be directly or indirectly affected by sea level rise.

2.1.7 Disaster and Emergency Assistance

Federal programs for emergency assistance to state and local governments and individuals may become increasingly important with increased incidence of drought in the Great Plains states, or flooding in coastal states or elsewhere. Although the programs themselves are inherently short-term, they are potentially important because funding levels may need to increase with progressive climate change that places people and property at risk from droughts and sea level rise.

2.1.8 Housing and Urban Development

Global climate change may diminish property values in areas adversely affected by drought, sea-level change, or other related economic impacts. Costs of mortgage insurance programs of the Housing and Urban Development Department, which are designed to insure lenders against mortgage losses, may increase. Property will certainly be affected in areas vulnerable to flooding and erosion from higher seas.

Federal programs affect urban and rural growth patterns through infrastructure grants. Federal programs for wastewater treatment construction grants, or highway construction, may affect population growth in areas adversely affected by climate changes. Low income home building and community or urban development programs may be affected by changed economic activity caused by global climate change.

2.1.9 Hazardous Waste

Sea level rise may affect the safety and hence the location of hazardous waste sites. The determination of cleanup priorities of the National Priorities List under the National Contingency Plan may be affected. EPA policies for land disposal and its alternatives may also be affected by changed climate and related hydrologic conditions.

2.1.10 Foreign Development Aid Assistance

Federal development aid programs can also affect, or be affected by, global climate change. The Agency for International Development (AID) provides technical assistance and grants and loans concerned with agricultural development, coastal zone management (Ecuador, Thailand, Sri Lanka), protection of biological diversity and wildlife, energy conservation, and infrastructure development, such as housing and sewage treatment facilities. The Forest Service, Fish and Wildlife Service, and National Park Service provide resource management training to developing countries. In addition, the United States is the largest contributor to the multilateral development banks that support large-scale programs in energy, agriculture, and urban and rural development. The Department of the Treasury, in cooperation with the State Department and other agencies, determines the kinds of multidonor projects the United States will support and the environmental analysis needed for informed development aid decisions. Recently the Treasury Department has been working with environmental organizations to develop guidelines for assessing the impacts of World Bank projects on tropical forests and wetlands.

2.2 RELATIONSHIP OF THE NATIONAL ENVIRONMENTAL POLICY ACT TO THESE FEDERAL ACTIVITIES

The feasibility of using EISs to assess global climate change impacts depends on the scope and duration of the federal action. An action that will have little discernible effect beyond 10 years is, at this stage, relatively insignificant. Simple program or engineering readjustments may be possible to avoid future adverse climatic effects on short-term federal actions. But a commitment to build a structure, develop a technology, make a plan, or take other actions likely to remain for 30 to 50 years or more may be significantly affected by climate changes occurring by the middle of the next century. Actions affecting a longer period, such as storage of nuclear waste, or actions directly or indirectly affecting the long-term existence of a species or a large natural ecosystem, may be most important to assess for climatic impacts.

Discussed below are examples of federal actions covered by NEPA that have potentially significant relationships to global climate change. Actions include plans, programs, regulations, and site-specific actions that may be subject to long-range planning and EIS requirements.

2.3 FEDERAL ACTIONS AFFECTING EMISSION OF GREENHOUSE GASES

2.3.1 Policies

The federal action allowing the most comprehensive analysis of greenhouse gas emissions and their climate effects is the Department of Energy's biennial National Energy Policy Plan. This "plan" is not, however, directed toward an action program, and it has not been incorporated into the EIS process. The last plan, in 1986, did not mention climate impacts of energy use. Similarly, the DOE report, *Energy Security*, prepared under §3102 of Consolidated Omnibus Budget Reconciliation Act of 1986, did not mention climatic effects of energy policies.

2.3.2 Programs

The Department of Energy's Clean Coal Technology Program spends over $300 million annually to support coal technology research and demonstration plants. DOE conducted an in-house analysis of the emissions of each coal technology as if it were fully deployed without economic constraints. It did not prepare an EIS because of statutory limitations of time and to protect project confidentiality. The EIS process may be used in future programs, however, depending on congressional action.

Regulatory program actions concerning energy may also require EISs. Examples include regulations of the Department of the Interior significantly affecting surface mining reclamation, outer continental shelf oil and gas production, and Nuclear Regulatory Commission regulations on nuclear power.

2.3.3 Projects

Many individual projects subject to EISs affect the contribution of greenhouse gases to the atmosphere. These include nonfossil fuel projects, like nuclear power plants licensed by the Nuclear Regulatory Agency and small hydroelectric facilities licensed by the Federal Energy Regulatory Commission, and coal- or oil-fired generating facilities that require regulatory permits from the Corps of Engineers, EPA, and other federal agencies. Because the impacts of individual projects on global climate change may be insignificant, regional or programmatic EISs can be used to give agencies a limited means to address some potentially important cumulative impacts of project decisions.

2.4 FEDERAL ACTIONS POTENTIALLY AFFECTED BY GLOBAL CLIMATE CHANGE

2.4.1 Plans/Programs

Two major long-range planning programs and assessments fall in this category: the Resource Planning Act Program of the U.S. Forest Service, and the Resource Conservation Act Appraisal of the Soil Conservation Service.

The Forest Service Resource Planning Act (RPA) Assessment and Program. The RPA Program, updated every 5 years, establishes a Forest Service plan for 191 million acres of National Forests and Grasslands and for Forest Service activities affecting state and private forests over the next 50 years. It is subject to the EIS requirement.

The RPA Program relies on scientific information and analysis in the Assessment, which must be made every 10 years and which is not subject to the EIS requirement. The 1979 Assessment and Supplement addressed water supply and demand issues, among other resource problems. These documents discussed increasing water scarcity in the 17 major river basins in 11 states in the Southwest and Midwest and widespread reductions in groundwater supply.

The documents assumed continuation of past climate patterns. The 1985 RPA Program established goals for the Forest Service to meet demands for timber, wilderness, water quality, wildlife, and other forest outputs without reference to impacts of climate change over the next 50 years. Although the Forest Service Research Program may become more active in climate issues in the near future, the 1990 RPA Assessment and Program assumes the continuation of past climate patterns.

Resource Conservation Act (RCA). This act requires the Department of Agriculture to undertake (in 1980, 1985, and every 10 years thereafter) an appraisal of soil, water, and related resources on the 1.5 billion acres of U.S. private land. Agricultural emissions can also be addressed. Although the appraisal is not an EIS, it is subject to public review in draft, and the RCA requires the Department of Agriculture to respond to the assessment in its programs and projects, such as those of the Soil Conservation Service concerning water resource and agricultural development projects.

The 1987 draft of the second RCA Appraisal (the Department is behind schedule) focuses on "conditions that have potential for limiting the capability of our resources to meet our needs." Among its conclusions relevant to climate considerations are the following:

- Salinization is lowering productivity in arid and semiarid lands;
- Most non-federal rangeland is in poor or fair condition;
- We are using more water, including groundwater, than we have supply in arid, semiarid regions;
- Irrigation water should be used more efficiently;
- Upstream flood damages are increasing in rural areas;
- Atmospheric deposition is causing problems and "popular concern."

The 1987 draft RCA Assessment notes that its projections do not include effects on yields from ozone changes or other atmospheric pollutants. It does not discuss potential climatic impacts.

2.4.2 Regional Programs

Federal agencies make resource commitments for regional programs and projects that are subject to long-range funding and environmental analysis.

Coastal zone plans. The Coastal Zone Management Act of 1972 allows states to receive federal grant support for coastal zone management plans that meet the act's requirements for managing economic development and implementing conservation practices. The federal government has approved 30 coastal zone management plans states and territories. Each plan has been accompanied by an EIS. One of the strongest inducements for state plans is the act's requirement that subsequent federal actions must be consistent with the approved plan. EISs on individual federal proposals in the coastal zone routinely address this question of consistency.

State coastal plans are not required to address sea level rise issues, but they can, and states may amend them to do so.

Energy-related river basin programs of the Tennessee Valley Authority (TVA) and Bonneville Power Administration (BPA) are subject to EISs. Programs subject to NEPA are carried out by the BPA on the Columbia River Basin, and by TVA in the Tennessee River Valley.

River basin planning and management and navigation projects, and irrigation projects. Although the federal government no longer routinely supports large-scale, comprehensive river basin plans, large river management and irrigation projects require long-range studies and EISs. Recent examples of regional projects include the Garrison Diversion Unit, Pick-Sloan Missouri Basin Program, and Multipurpose Water Project of the Bureau of Reclamation. Regional river basin planning is carried out by the Delaware River Basin Commission, the Interstate Commission for the Potomac River, and other interstate commissions.

2.4.3 Site-Specific Plans or Projects

National Forest Management Plans. Plans required for each national forest under the 1976 National Forest Management Act are subject to EISs and must be reviewed every 10 to 15 years. The plans are basic guides for allocating uses within each forest, including long-range timber harvest schedules, road development, and decisions to cut old growth timber. Each document can incorporate climate impacts on a regional basis into the plan, but none does so now.

Resource Management Plans. The Bureau of Land Management, responsible for managing over 400 million acres of public land, prepares comprehensive land-use plans under the Federal Land Policy and Management Act of 1976. The plans resemble forest plans in scope, are subject to EIS requirements, and must be amended or revised as needed. All BLM actions must be consistent with the approved plans. Citizens participate through the NEPA scoping process and comments on the draft plan/EIS. More than half of BLM's public lands are in the 11 contiguous states of the West, and most BLM land is rangeland. Climate change impacts have not been incorporated into BLM plans.

Habitat Conservation Plans. The Endangered Species Act amendments of 1982 requires permits from the Secretary of the Interior for private actions that might result in the "incidental taking" of habitat that might jeopardize the survival of a threatened or endangered species. Permits require compliance with a Fish and Wildlife Service Habitat Conservation Plan. Such plans have been necessary for large development projects at San Bruno Mountain, California, and Key Largo, Florida. Four more are being prepared to protect the Least Bell's Vireo in what is essentially a comprehensive plan for the protection of riparian areas in San Diego County, California. Unlike the approximately 200 species recovery plans of the Service, Habitat Conservation Plans are subject to EIS requirements.

Public works projects. Many coastal projects subject to EIS requirements have a long-term life and may be significantly affected by rising sea levels. These include highways (Federal Highway Administration), beach erosion control, harbor improvements or levee construction (Corps of Engineers), or public land management projects, such as the National Park Service proposal for protection of the Cape Hatteras Light House.

Water supply projects. The Corps of Engineers, under §404 of the Clean Water Act, must authorize reservoir and water supply projects affecting U.S. waters. A recent example is the Corps §404 permit evaluation and EIS on the proposed Metropolitan Denver Water Supply Project to meet Denver's water needs through the year 2035. The EIS assumed continuation of past precipitation and other climate patterns.

Nuclear waste programs. Nuclear waste disposal sites are subject to EIS requirements. Because of long-term impacts the Department of Energy has included climate change factors in EISs on uranium mill tailing disposal and nuclear waste from the Hanford Defense site.

2.4.4 Foreign Assistance Programs

Programs of the Agency for International Development (AID) are subject to NEPA, and, although few actions require EISs, environmental assessments are occasionally needed. AID grant or loan commitments of 5 or more years may address programs such as energy conservation, coastal zone management, biological diversity, or programs concerned with desert encroachment or deforestation of tropical forests. Long-term AID projects may concern agricultural, sewage treatment or other actions in coastal regions highly vulnerable to rising sea levels, such as the heavily populated Nile and Ganges deltas.

CHAPTER 3

EXAMINATION OF SELECTED FEDERAL AGENCY LONG-RANGE PLANNING AND EIS PRACTICES

General approach. This section evaluates a selected group of federal planning and EIS processes relevant to future impacts of temperature increases, precipitation changes, and sea level rise. The following topics are analyzed:

- Water resource planning and assessment processes of the Corps of Engineers for flood control, navigation improvement, and other Corps planning processes concerned with private permits affecting U.S. waters;
- National forest management plans and Resource Planning Act programs carried out by the Forest Service;
- Refuge management and endangered species programs of the Fish and Wildlife Service;
- Coastal construction, protection, and permit actions of federal agencies that may be affected by sea level rise.

To illustrate existing long-range planning and EIS processes and their potential application to climate impact issues, examples have been chosen from among current federal actions on which EISs have been prepared within the past 12 months. The examples show how statutory differences affect the scope of agency decisions and the nature of EISs, and how these factors may affect greater consideration of climate issues in the future.

3.1 THE U.S. FOREST SERVICE

The National Forest System. The United States has 1.6 billion acres of forest and range lands. Of these, the National Forest System contains 191 million acres, including about 20 million acres in Alaska. Although about three-fourths of the remainder are in the 11 western contiguous states, constituting about one-fifth of the land there, the system includes land in nearly every state. National forests provide about 25 percent of our national demand for timber per year. They include approximately 157 of the 261 identified ecosystem types in the United States in wilderness areas (Davis, 1987). More recreation takes place on these lands than any other public lands, including our national parks, amounting to 43% of visitor hours for all federal recreation lands. Because climate change may significantly affect these forest resources in the long-term, the question is whether and how it might be addressed in existing planning and EIS processes.

3.1.1 The Forest Service Planning and EIS Process

With passage of the Resource Planning Act of 1974, Congress ratified the Forest Service's national planning approach, and with the National Forest Management Act of 1976 it established specific requirements for forest planning processes for each national forest in the 191 million-acre National Forest System. The Forest Service subsequently integrated its NEPA process into these planning requirements.

The Resource Planning Act As Amended

This act required the Forest Service to establish a periodic, long-term Renewable Resource Program, based on a periodic Renewable Resource Assessment of the nation's forest, range, and associated renewable resources. The purpose of these requirements was to "promote a sound technical and ecological base for effective management, use, and protection of the Nation's renewable resources" (§2(4)). Congress declared that because most forest and rangeland was in private and other non-federal ownership, the federal government should be a "catalyst" to help other landowners manage their resources efficiently over the long-term. The

Assessment and Program can help states and other entities plan the protection and management of renewable resources on non-federal land.

Renewable Resource Assessment. Congress required the Assessment to be prepared in 1975, 5 years later, and every 10 years thereafter. The Assessment was to include analyses of renewable resource supply and demand. Because the Assessment does not recommend agency action it is not subject to the EIS requirement of NEPA. Nevertheless, the Assessment results are included in Forest Service EISs. The Assessment also offers an opportunity for the Forest Service to examine basic assumptions and alternative program directions for its 50-year period. The Forest Service has prepared two resource assessments since 1974 as required: one in 1975 and another (draft and final) in 1980, which was supplemented in 1985. It is now preparing the 1990 Assessment.

Renewable Resource Program. Congress required a Program to be sent by the President to the Congress that responds to findings of the Assessment. The Program must respond to the "principles" of the Multiple-Use Sustained Yield Act of 1960 and to NEPA. It must be submitted every 5 years, beginning in 1975, and it must cover the ensuing 50-year period. The Program must include, among other features, an inventory of needs and opportunities for public and private investments, specific Program outputs, benefits, and costs, and recommendations concerning objectives and opportunities to improve forest and range resources. Renewable Resource Programs have been prepared every 50 years since 1975. The third and latest Forest Service Program, prepared in 1985, addresses renewable resource program directions from 1985 to 2030.

Each year the President must send Congress reports on how his proposed budget would meet the policies of the Program, Assessment, and policies of the Forest Service.

The National Forest Management Act

The National Forest Management Act (NFMA) of 1976 required long-range, integrated resource plans for each unit of the National Forest System. Congress required that forest plans must be revised at least every 15 years (EIS requirement), include multiple use concepts, identify lands not suitable for timber harvesting, prohibit harvesting on such lands for 10 years, and review such land classifications every 10 years. In addition, Forest plans must comply with NEPA.

In addition, the forest plans must comply with regulations developed with the advice of a Committee of Scientists. Congress required that the regulations must ensure, among other things, provision for the following: diversity of plant and animal communities; research and field monitoring to protect against loss of land productivity; intensified forestry consistent with the Multiple Use and Sustained Yield Act; protection of soil, slope and watershed conditions; assured reforestation within 5 years after timber harvest; protection for streams, streambanks, shorelines, lakes, wetlands and other water bodies where timber harvests might adversely affect water conditions and fish habitat; and protection of forests from specified adverse effects of clearcutting and other silvicultural harvesting practices.

By March 1988, approximately 83 out of 123 plans had been issued in final form, and 40 had been released in draft for public review.

The Forest Service has a regional level planning program, which it has added by its own regulations, that results in a Regional Guide to help each National Forest unit implement the Program. The Regional Guide is not itself the subject of an EIS.

3.1.2 The Planning Process in Practice

Case Example: The Forest Service Forest Planning and EIS Process in the Nez Perce National Forest

Individual forest plans and EISs assess alternative management programs over a 10- to 15-year period. The Nez Perce National Forecast Plan and EIS (U.S. Department of Agriculture, 1987), completed in October

1987 offers a good example of this process, and one that EPA's own review found to be of high quality (Kaldjian, personal communication). Like other forest plans, the purpose of the Nez Perce plan and EIS was to provide specific direction for projected timber sale levels, monitoring requirements, and other standards and guidelines, for a maximum of 15 years. The plan/EIS is, however, only a guide to timber and other output levels, which may be changed as external demand conditions change.

The forest resources. The Nez Perce National Forest contains over 2.2 million acres in Idaho County, Idaho, covering steep and rugged, high-elevation forests in a climate made milder than its high latitude because of Pacific Ocean climatic effects. Its streams are important to the anadromous fishery of the Columbia River, and it provides nationally important habitat for elk, among other wildlife. It contains the Gospel-Hump Wilderness and parts of three other wilderness areas, in addition to four wild and scenic rivers. Over the past decade the forest provided an average of nearly 100 million board feet of timber annually.

The Nez Perce planning/EIS process. The process officially began with a public Notice of Intent to prepare a plan and EIS in October 1979. It ended 8 years later with completion of a final EIS and publication of a Record of Decision by the Regional Forester. During that time the Forest Service dealt constantly with the public and identified over 800 public concerns that were reduced to 13 major issues.

To develop alternatives the Forest Service began with the alternatives required by regulations or policy, such as maintaining the current program, classifying all roadless areas as wilderness, and several others. These were then analyzed to determine where they fit in the range of forest outputs: timber, fisheries, wildlife habitat, water quality, minerals, and recreation.

The Nez Perce example illustrates the complexity and importance of Forest Service planning/EIS processes and how they might in the future respond to climate change. The process allows the Forest Service to make significant decisions over a decade or more concerning the production, biological makeup, appearance, and economy of the forest based on the results. In Nez Perce the Forest Service chose an alternative that is targeted to produce 11 million board feet more each year than the previous decade's average. It designated 140,000 acres as unsuitable for timber production, made areas available for mineral development, planned anadromous fish habitat management to achieve 87% of its potential, and planned 830 miles of additional roads. Climate factors were not addressed in this plan/EIS, but future climate changes could affect Forest Service decisions on timber sales and its confidence in reforestation.

3.1.3 Applicability of the Forest Service's EIS Process to Global Climate Issues

Global climate issues have not yet been addressed in the Forest Service planning process, either at the national, regional, or forest level. Opportunities for doing so exist in the future, however, at each of these levels.

Assumptions underlying the Assessment. Climate change was not mentioned in the RPA Assessment, either among the explicit assumptions or elsewhere. Assumptions that climate patterns of the past would continue into the future are implicit throughout the Assessment. An example is the conclusion that precipitation patterns of the past would continue, although it noted the wide regional variability of precipitation from year to year.

The Assessment does state at the outset, however, the assumptions that the Forest Service believes will influence future demand and supply trends up to the year 2032. As modified by the 1984 Supplement, they are increases in population, gross national product, and per capita disposable income. It assumed that energy costs would increase relative to other general prices, that capital would be available to increase renewable resource supplies, that institutional and technological changes of the past would continue, and that demands for forest and range resources would increase.

Treatment of global climate impacts in the 1989 Assessment. The 1989 Assessment, now under preparation for final release in the summer of 1988, will follow the same basic approach as earlier assessments.

The section on basic assumptions, to be published as a 40-page appendix to the Assessment, will continue to assume the climate patterns of the past. No sensitivity analyses are conducted for the assumptions that are made.

Opportunities to use the Assessment to address climate impacts. The Forest Service employs a Timber Assessment Market Model (TAMM) to help simulate timber supply and demand futures. The model is a spatial equilibrium model that provides an integrated means for considering the effects of prices, consumption, and production of timber markets. If, therefore, it was determined that global climate change might result in a certain percentage reduction of timber growth and timber inventory, TAMMS would allow the Forest Service to determine how it might affect overall U.S. timber supply and demand. This result could then be factored into the Resource Program and the regional and forest level targets for timber production.

Even without this model, however, the Assessment could develop regional guidelines on climate change scenarios and forest impacts that each forest unit should consider in developing their plans. More than the RPA Program, the Forest Service may be most receptive to future use of the Assessment as a guide to Forest Service response to climate change (Ketcham, personal communication).

Addressing climate issues at the Forest level. Although opportunities exist to address climate impacts in EISs prepared on regional guides of the Forest Service, as required by the National Forest Management Act, climate impact analysis may be most meaningful when it can be addressed at the forest level. Major forest changes are possible if temperatures rise and conditions are drier or wetter. Simple scenarios of this kind may be speculative now, but the Nez Perce experience suggests that they can be considered in the future. For example, Forest plans and EISs might first identify the forest resources likely to be most sensitive or resilient to climate impacts in the particular region, such as fisheries and water quantity and quality, old growth habitat, and other timber inventory. Then they could assess the sensitivity of these resources to different climate scenarios that appear reasonable in the region. Lastly, they could establish rigorous monitoring programs to assess ongoing experience with reforestation, rehabilitation of wildlife habitat, water quality, improvement, and protection of biological diversity, to ensure rapid response to changed environmental conditions during the 10- to 15-year plan.

Responding to climate issues within the Resource Program. The RPA can address program effects based on data in the Assessment. Further analysis should be made of ways in which future Resource Programs could address climate impacts that might affect forest resource outputs. The Program might, for example, guide federal, state, and private monitoring of reforestation, and protection of gene pools, endangered species, and ecosystems that may be affected by climatic change.

3.2 THE CORPS OF ENGINEERS CIVIL WORKS PROGRAM

Responsibilities. The Corps Civil Works Program has historically focused on providing navigational improvements, flood control, hydropower, and coastal shoreline protection. More than a century ago the Corps was charged with reducing flooding and improving navigation in the lower Mississippi River basin. Its jurisdiction expanded to include authority to develop a national inland waterway system, regulate discharge of refuse into and obstructions to navigable waters, and to establish comprehensive hydrologic data bases, long-range models to project flood peaks and durations, soil erosion and sedimentation rates, coastal water levels, and other information useful for project design studies. In recent decades, municipal water supply and aquatic recreation have been added as additional purposes of Corps multipurpose projects.

The Corps NEPA process. Corps water resource projects and permit actions are subject to NEPA. The Corps prepares EISs for legislation, feasibility reports, operations and maintenance activities, regulatory permits and real estate management, and disposal actions. Because of their differences, the Corps project and regulatory NEPA processes are summarized separately.

3.2.1 Water Resource Projects

Water Resource Planning and the EIS process

The project planning process begins with an initial survey by the Corps that examines a specific water resource problem and possible remedies. If a project looks favorable and has local, state, and congressional support, a feasibility study will examine project economics, social and environmental impacts, and specific design alternatives. The Corps will then seek congressional authorization for a project. Upon congressional authorization, the Corps will continue to prepare more detailed engineering studies and design. It will seek construction appropriations if local and state project financing continues, and when it is ready to acquire land and build.

Principles and Guidelines for Water Resource Projects

The Principles and Guidelines is a policy document that establishes national objectives for planning and evaluating federally sponsored water resource projects, but not regulatory actions. The document has gone through several changes, from standards to regulations to guidelines, since the early 1970s, and the present form was adopted in 1983. The Principles and Guidelines require every Corps planning document to analyze a number of factors in specific ways. For example, they require projects to be examined for economic and environmental benefits and costs. They establish a number of economic criteria for computing economic benefits and costs, including the discount rate for benefit-cost analyses, which is now established at nearly 9%. The discount rate significantly affects the long-term economic viability of projects. When the discount rate is high, to have a positive benefit to cost ratio projects must have relatively low initial costs and relatively high, and early, economic benefits.

Evolution and Present Focus of Water Resource Planning Programs

Water resource planning processes have undergone several changes over the past 20 years. The 1965 Water Resources Planning Act required Level A "framework" studies of the major river basins in the United States to address their hydrology, flooding conditions, irrigation, hydroelectric, and other capabilities. By 1980 several such studies had been completed. Level B studies were also established to examine smaller river basin subsystems, focusing on project-level needs, such as water supply, water quality, flood control, and navigation requirements. After NEPA was passed, a number of these studies were prepared in conjunction with EISs (Smythe, personal communication). But in 1981 the Water Resources Council was abolished, and funding was eliminated for the federal river basin commissions that helped develop water resource plans. No requirement now exists to update Level A studies or to prepare Level B studies, and there is no federally directed, integrated regional water resources planning process. Corps projects have also become smaller, and funds are lower for long-range environmental monitoring and projections and trend analyses. Integrated regional planning regional basis has been deemphasized and the Corps focuses on individual water resource projects.

Links Between Corps Long-Range Planning Studies and the EIS Process

River basin studies. Over the past 10 years or so, the Congress required the Corps to conduct several major long-range and/or large scale studies with environmental components. These include the Great Lakes Navigation/Shoreline Protection studies (ongoing from the mid 1970s); several Chesapeake Bay studies; the Upper Mississippi River Navigation Study (1978-80); the National Waterways Study (1980-81); and the National Hydropower Study (1981). More recently, the Water Resources Development Act of 1986 authorized several national studies on climate change and rising seas, infrastructure decay, and an inventory of environmental resources, but the studies have not been funded.

In 1979, the U.S. Army Engineers Institute of Water Resources conducted studies on the hydrologic and geomorphologic effects of warmer and drier, and cooler and wetter, climate conditions in the United States (these studies were never published, but see Hanchey et al., 1987). Included was an analysis of the sensitivities of the 18 major river basins in the United States to the four scenarios. Direct links between these studies, water resource planning documents, and Corps EISs appear to be tenuous, however, even though individual EISs on projects often reveal the importance of broader studies and planning data in developing proposals or alternatives.

Even though climate change is not formally and separately integrated into the Corps' planning process, the Corps does analyze hydrological, ecological, social, and economic impacts in detail through engineering design studies that focus on project performance, reliability, and risk-cost effectiveness. Such analyses are now routinely conducted for most alternative solutions recommended by the Corps, including nonstructural flood warning and evacuation plans. These analyses assume a steady-state climate, but project designs may incorporate the climate variations likely to occur during a project's lifetime.

One example of a major Corps project with significance to climate change issues is the New Orleans to Venice Hurricane Protection Project, for which a final supplemental EIS was recently prepared. (The case is discussed in Section 3.4, Coastal Zone Management.) In that case an alternative levee protection scheme developed 10 years after completion of a Final EIS, in 1986. The recommended new plan reflected information developed by the Corps on downstream importance of natural accretion of sediment from the Mississippi. Although it did not address future climate change as such, coastal subsidence and sea level rise were major concerns.

3.2.2 Regulatory Program

Permit Requirements

Permits are required from the Corps of Engineers for the construction of dams, dikes, or other structures in or over U.S. navigable waters under the Rivers and Harbors Act of 1899. Permits are also required for the discharge of dredged and fill material into waters of the United States (a more inclusive category) under §404 of the Clean Water Act, and the Corps must comply with Guidelines prepared by the Environmental Protection Agency. The Corps receives and reviews about 14,000 permit applications annually, nearly all for small projects.

The NEPA Process

Because Corps permit actions are subject to NEPA it routinely carries out environmental assessments, from checklists to lengthy analyses, or EISs. From 1970 through 1986 the Corps prepared about 1,800 final EISs under the Civil Works program, of which 404 concerned regulatory permits. Approximately 20 permit EISs were prepared in 1986, down from a high of 51 in 1975, constituting about half of the total Corps EISs that year (Studt, personal communication).

The Corps relies on its permit applicant to provide most of the data necessary to evaluate needs for a typical EIS evaluation, and although it is responsible for the content of any EIS it relies heavily on the applicant's data and consulting reports. EISs on large projects, however, such as an industrial plant or airport, require the Corps to gather and analyze data, entailing substantial commitments of Corps staff and resources.

Scope of the NEPA process. The Corps must often analyze the significant environmental impacts of an entire project rather than the impacts of the particular pier or other construction element that requires a regulatory permit. Recent revisions of the Corps' NEPA procedures allow the Corps to limit its EIS analysis to the significant impacts of the action requiring a permit. Where there is substantial federal involvement in the proposed project the analysis is enlarged.

Comprehensive Regulatory Studies

The Corps often faces practical problems in trying to evaluate cumulative impacts of regulatory permit proposals in a particular area, so it has supported comprehensive analyses that can lead to better, and more efficient, regulatory decisions. In particular it has encouraged the development of Special Area Management Plans, primarily in the coastal zone, as discussed in Section 3.4. It has also supported comprehensive EISs inland that can help the Corps and local communities identify long-range needs and objectives. The Trinity River Regional EIS is an excellent recent example.

Case example of an areawide EIS -- Trinity River Regional EIS

The problem. In late 1984, in response to concerns of local government officials, the Corps Fort Worth District determined that it lacked the necessary information to evaluate, as required by NEPA, the cumulative impacts of the many unrelated development proposals for the Trinity River and tributaries in Dallas, Denton, and Tarrant Counties, Texas. The Corps had approved several major projects within the previous 10 years, others not yet built, and it expected more permit applications for river or floodplain modifications. Increased runoff and reduced storage capacity upstream had reduced the flood control capacity of tributary levees and increased flood dangers downstream. High quality wildlife habitat was also in danger of being lost. Because they individually or cumulatively affected flood protection possibilities, with related economic and environmental impacts, the Corps looked for a practical way to evaluate the different regional development scenarios.

The EIS process. The Corps and the local governments favored a planning approach using a regional EIS to develop and disseminate information, obtain essential public participation through the scoping and comment process, and help coordinate the many public agencies involved. The Corps agreed that the North Central Texas Council of Governments that it should serve as the convener of the many affected city and county governments, and should seek congressional funding for the effort. A Final EIS was completed in October 1987.

Study conclusions. The 2-year study began with a baseline flood condition drawn from existing Corps' hydraulic and forecasting models for the two major tributaries, as updated by recent floodplain and watershed developments. No precipitation or other effects of future climate changes were analyzed. Alternative development scenarios included: the future without watershed development; two maximum development designs; §404 permits in the floodway fringe only; no §404 permits; and a maximum environmental quality approach, including greenways, recreation, and habitat protection.

The study concluded, first, that there was widespread lack of protection against the Standard Project Flood--the most severe likely to occur in the area--which might cover nearly 70,000 acres, including 15,000 acres of residential or commercial/ industrial property, and which might cause over $3.5 billion in property damages. Second, it found that Corps permitting strategies could significantly affect this damage by allowing or prohibiting development of 2,800 acres within the zone. Other findings concerned valley storage needs and opportunities and comparisons between Federal Emergency Management Authority floodway delineations, which were intended to limit a rise in the 100-year flood water surface elevation, and the effects of mandatory limits on encroachment in the main floodway, which would actually achieve the result intended.

3.2.3 Applicability of the Planning/EIS Processes to Global Climate Issues

Inadequate comprehensive planning/EIS processes for water resource projects. If global climate change will affect watersheds through temperature rise and changes in seasonal and annual precipitation, environmental studies may need to give more attention to regional river basin impacts in order to support individual Corps' projects. Unlike the Forest Service, the Corps is not required to carry out comprehensive national or regional planning. The Corps has extensive environmental analysis capabilities, but existing resource planning/EIS mechanisms are increasingly focused on specific projects. They do not address broad-scale issues, problems, needs, and changes affecting river basins.

Potential for use of project level EISs. At the project level the Corps has the capability to use the EIS process as a useful public disclosure document that examines the implications of climate change on a proposed project and its reasonable alternatives. It has been said that the Corps has been designing large water resource projects with so much "buffering and redundancy" that they do, in fact, encompass reasonably anticipated climate change. Smaller urban projects are more susceptible to weather variations (Hanchey et al., 1987). In any event, a Corps project EIS can explicitly disclose the uncertainties about climate change and the implications of climate change on the proposed design and reasonable structural and nonstructural alternatives.

A project level EIS can play a valuable role in disclosing information and for formulating choices concerning long-term climate impacts, notwithstanding the fact that its utility to water resource agencies has been a subject of debate since the early 1970s. Arguments have been made that the Principles and Guidelines are so detailed, comprehensive, and rigorous in their planning and evaluation requirements that they incorporate EIS requirements and make EISs unnecessary, as a practical matter. Indeed, the Corps typically conducts detailed technical analyses for its design studies, and environmental considerations have been integrated into decision processes at early and continuous stages, which is one of the goals of NEPA. On the other hand, the EIS remains practically valuable as a document that requires full disclosure of impacts and alternatives to interested members of the public, the Congress, and to other government agencies at all levels. Although it may only summarize analyses made in more detailed documents, it offers invaluable opportunities for public understanding of, and participation in, the choice of alternatives. Given the political as well as technical choices that may be posed by long-term projects potentially affected by climate change, the EIS process can be an asset to decision makers too.

For example, an EIS on a large-scale flood control or reservoir project with a lifetime of 50 years or more can be made useful to decision makers and the public. It can display an alternative that would show the protection levels of a project, or other water resource benefits, such as a more flexible, more resilient flood control system, that might exist under scenarios of more or less rainfall, earlier snowmelt, and so forth. Based on comments received on an EIS, the decision maker might decide that the costs of trying to accommodate future uncertainties, including more severe extreme floods, are not justified. He might determine that higher levees, for example, could adversely affect coastal wetlands deemed publicly valuable, or that higher prices for water might stimulate water conservation that could reduce structural requirements until forecasts of future climate conditions were more reliable. Short of becoming an impractical, speculative document, an EIS on a Corps (or other governmental) water project can also disclose to the public the risks related to climate change, the uncertainties posed by present climate information, and the implications of these factors for public decisions on water resource use. As climate research is able to focus increasingly on the practical concerns of engineers, planners, taxpayers, and property owners, these EISs can offer a practical outlet for data and analysis carried out in other studies.

Reassessment of principles and guidelines. To respond in advance to long-term climate changes the Corps and the other water resource agencies may need to reassess the Principles and Guidelines. Another problem is the impact of high discount rates. A project intended to protect an urban area from rising sea level in 50 to 100 years is unlikely to be justified by present discount rates. The economic bases for project justification is not sensitive to long-term slow changes in environmental conditions and values.

Long-term regional planning/EIS capabilities in the regulatory program. The Trinity River EIS illustrates how the Corps' permit program can support local interest in areawide planning for long-term use of floodplains and waterways where no comprehensive planning capability previously existed. The Corps was open to the regional EIS because comprehensive planning approaches appeared more practical and cost-effective than its usual case-by-case permit review, which has proved especially weak in addressing cumulative impacts. Strong local government and public support for a regional approach was essential, however. Such approaches are infrequent because Corps use of regional EISs and Special Area Management Plans is limited by tight congressional budgets for its regulatory program (Studt, personal communication).

Opportunities and needs to address climate change in Corps planning/EIS processes. Although the Corps' EIS/planning process is often *ad hoc*, the Corps' capacity to conduct comprehensive long-range studies and EISs is extensive. Its integration of environmental factors into water resource planning over the past 20 years illustrates its ability to adjust to new data and public concerns about environmental impacts. These concerns have strongly affected Corps projects; of the 600 water resource planning studies subjected to feasibility reports between 1976 and 1987, only about 10% were authorized for construction, and still fewer have received appropriations.

In the future there appears to be no procedural or analytical barrier to explicit climate analysis in Corps project level and regulatory permit EISs where proposals will have long-term impacts. Project-level EISs and regional or areawide EISs on regulatory proposals can address climate change scenarios and relate them to site-specific impacts. Although climate factors were not analyzed in the Trinity River EIS, they could have been based on information gathered in other studies by the Corps. The Trinity River EIS explained the uncertainties and risks of current development patterns, based on past climate records, and it could easily have examined the sensitivity of the various development options to climate changes. With adequate funding, similar EIS analyses can be developed elsewhere in the country where local governments have concerns about long-term areawide approaches to floodplain and water resource use.

3.3 THE FISH AND WILDLIFE SERVICE

3.3.1 The National Wildlife Refuge System

The U.S. Fish and Wildlife Service (FWS) is responsible for management of about 90 million acres in the National Wildlife Refuge System. This system includes National Wildlife Refuges of about 88 million acres, of which 77 million are in Alaska. Another 1.7 million acres are in Waterfowl Production Areas. Individual refuges range in size from a half acre to 22 million acres.

The system grew gradually since the first congressional authorization in 1905, and refuges were steadily added by congressional acts. Congress established various mechanisms for funding the Secretary of the Interior's management and acquisition of refuges and expanded the FWS authority to acquire refuge lands to protect endangered species. Approximately 30 refuges have been established by Congress with others created under provisions of various other acts. National refuges are found within all states except West Virginia.

Environmental Management of Refuges. Refuges require careful management by the FWS according to their purposes and the significance of threats from outside impacts. Outside threats include pesticide and other pollution, changes in hydrology, human encroachment, and successional changes in habitat that may affect species composition. It may modify habitat, particularly wetlands and water resources, to protect or enhance species of particular concern, including endangered species (for example, the Atwater Prairie Chicken National Wildlife Refuge in Texas), migratory birds (the Blackwater National Wildlife Refuge in Maryland), or large mammals (the National Bison Range in Montana). Refuge management may include programs to allow economic use (for cattle grazing, oil and gas production, timber harvesting), hunting for birds and animals, subsistence hunting by rural residents, fishing, and a variety of recreational activities. These uses may be permitted if the refuge manager determines that the proposed use is compatible with the purpose of the refuge (Audubon Wildlife Report, 1987). Portions of the receipts from these economically contribute to local governments in lieu of property taxes. Less intensive, "natural" management prevails on the 67 refuge wilderness areas of nearly 20 million acres. Maintenance of biological diversity on nearly 5 million acres of scientific reserves has become increasingly important to the FWS (Office of Technology Assessment, 1987).

3.3.2 The Refuge Planning and EIS Process

The National Wildlife Refuge System does not have a statutory long-term directive like the National Forest System. Refuges are managed according to guidelines of the FWS Refuge Manual. FWS actions are subject to NEPA, and its national, regional, and field programs are regularly addressed in EISs.

National Refuge System EIS. Like the Forest Service, the FWS seeks to integrate its EIS process into its required planning process. The FWS Division of Refuge Management prepares a 10-year Service Management Plan that sets program goals for all 442 national refuges. A refuge system programmatic EIS was completed in 1976 (U.S. Fish and Wildlife Service, 1976), which assessed refuge impacts of various funding levels. A new program EIS will be completed in 1988 that will exclude budget issues and examine the impacts of four operational alternatives for the national refuges: (1) continuation of current programs; (2) maximum economic exploitation for commodities and recreation; (3) no management, allowing natural succession and only carrying out the activities mandated by legislation; and (4) management for nonconsumptive uses as under option 1 and prohibition of consumptive uses under option 3, such as hunting, fishing, and trapping. To prepare the EIS, the FWS held six "scoping" meetings around the country in 1986 (Furness, personal communication).

Regional and unit level plans and EISs. Regional directors approve plans relating national objectives to endangered species or species of special concern. Individual refuge managers prepare management plans, and annual work plans, with a horizon of 5 years to 100 years (for forestry management). Approximately 100 master plans have been prepared, many of which were subjects of EISs, but these have been largely discontinued recently. Whether such a plan is required, and whether an EIS is necessary, depends on the refuge manager's determination of the significant issues and impacts affecting each area. Chief among the factors affecting an EIS requirement are questions and controversies concerning the compatibility of proposed economic or recreational uses with the refuge purposes.

Case example: The FWS planning and EIS process for the Upper
Mississippi River National Wildlife and Fish Refuge

The Upper Mississippi River (UMR) National Wildlife and Fish Refuge illustrates how large the scope and complexity of the FWS planning and EIS process can be. Congress created the refuge with unusual and difficult management constraints, owing to the navigational importance of the Mississippi River. It was established in 1924 (P.L. 268) to carry out the Migratory Bird Treaty with Great Britain by protecting critical migratory bird breeding and other habitat along the Mississippi between Wabasha, Minnesota, and Rock Island, Illinois. The refuge is the longest in the 48 states, extending 261 miles along the Mississippi and encompassing 194,000 acres in Minnesota, Wisconsin, Iowa, and Illinois. It forms a long north-south biological corridor that climatologists and biologists consider potentially valuable for species migration stimulated by global climate change.

Environmental values. The refuge lies along the floodplain of the Mississippi, which was, until the early 1930s, a free-flowing river. Today the locks and dams constructed by the Corps of Engineers create reservoir pools just above the dams, extensive marshes and backwater lakes farther up, and heavily timbered, meandering channels and side channels at the upper end. This environment supports great ecological diversity owing to its sheltered floodplain and north-south expanse (U.S. Fish and Wildlife Service, 1987). Species include a variety of migratory waterfowl in the marshes and open pools and possibly the largest winter concentration of bald eagles outside Alaska. The refuge supports numerous sport and commercial fish and habitat for such endangered or threatened species as the peregrine falcon (reintroduced), Indiana bat, the Higgins eye pearly mussel, and other plants and animals. The FWS estimates that the substantial recreational use of the area for boating, fishing, and birding, amounts to about 3 million user days per year, which is greater than any other National Wildlife Refuge.

Management and planning process. Congress authorized the FWS to enter into agreements with the Corps of Engineers and the neighboring states, and established FWS authority to plan and manage the UMR refuge. Because the Corps of Engineers constructed locks and dams on the river and owns more than half of the refuge, the FWS must cooperate with the Corps to control activities within the refuge.

In 1974 the Corps and the FWS agreed to develop a long-range management strategy for the Upper Mississippi River under the Upper Mississippi River Basin Commission, which included Missouri, Wisconsin, Iowa, Illinois, and Missouri, the Corps, FWS, EPA, Coast Guard, and Soil Conservation Service. Congress authorized an interagency task force known as the Great River Environmental Action Team (GREAT) and a Great River study 2 years later to address the "total river resource requirements, including navigation, effects of increased barge traffic, fish and wildlife, recreation, watershed management and water quality" (1976 Water Resources Development Act). The two studies have been completed on segments of the river—GREAT I, and GREAT II.

Cooperative state-federal planning work has continued. After the River Basin Commission was terminated in 1981 (see discussion under Corps of Engineers), an Upper Mississippi River Basin Association was formed in December 1981 to include the five states, with federal agencies participating as advisory members. In 1986 Congress approved the Association's Comprehensive Master Plan "as a guide for future water policy" in the region (Water Resources Development Act of 1986). After that the five states and several federal agencies began several programs to carry out environmental management, monitoring, and coordination. Additional work has been done to improve the inventories and analyses of GREAT I and II, including use of a computerized Geographic Information System on the location of wildlife species and recreation activities. The two Corps districts completed a Land Use Allocation Plan to zone for wildlife management or low-density recreation.

The UMR Wildlife Refuge EIS. The purpose of the UMR EIS was to analyze, and obtain public views on, alternative measures to carry out the refuge master plan. Water quality has been the major concern of the refuge because of farming impacts, development in the floodplain, and increased river traffic. Significant adverse impacts on the refuge include nonpoint pollution from farms and urban areas. Sediment deposits, primarily from farms, have affected backwater areas in particular. Extensive navigation use can keep sediments suspended and causes shoreline erosion when traffic occurs at low or high water. Management of water levels to enhance wildlife is limited because levels must be maintained for navigation. The dredging and disposal of material from the shipping channel has also harmed water quality.

Other significant environmental impacts include changes in wildlife habitat conditions caused by deteriorating conditions in the floodplain and declines in migratory species due to loss of habitat elsewhere. Recreational boating may be stressing migratory birds at rest in the river, and declines have been noted for fish species dependent on long movement along the river.

The EIS analyzed and compared the effects of five basic alternative management programs on the major issues of concern: water quality, wildlife management, fishery management, barge and commercial navigation, and management of the refuge for recreation and use. The selected alternative had the support of most of the approximately 30 government agencies and organizations commenting on the EIS.

3.3.3 Applicability of the EIS Process to Global Climate Change Issues

The FWS has primary responsibility for protecting wildlife and endangered species, and global climate change adds another potentially significant stress to other impacts that are already daunting. Despite institutional constraints on the FWS management of certain refuges, its planning and EIS process offers several opportunities to address global climate issues in the future.

The UMR case example illustrates how climate change scenarios might be applied to regional watershed studies by federal and state agencies and refuge management EISs of the FWS. The UMR EIS analyzed ways to reduce rates of decline in water quality and wildlife habitat. It highlighted the importance of the refuge as an important north-south biological pathway and haven for biological diversity. It discussed the constraints on refuge protection resulting from the policy priorities that Congress gave to navigation. It noted the adverse impacts of recreational and other human uses on long-term protection of biological resources, and it highlighted needs for monitoring of migratory bird populations, attention to fish habitat study and enhancement, protection of biologically important private lands within the refuge, and the establishment of scientific research areas. It relied in part on studies undertaken by the states and federal agencies in the region.

Many of the fish and wildlife impacts and management responses addressed in this EIS, and other refuge management EISs, are likely to be climate sensitive. Whether long-term global climate warming causes drier or wetter conditions, they may significantly affect FWS refuge management decisions. For example, a future refuge plan/EIS on the UMR refuge might usefully analyze available data on the impacts of climate change on migratory bird habitat in the central flyway, or on other endangered species and wildlife. The impacts of global climate change may make the UMR refuge and many other refuges increasingly valuable as well as vulnerable.

In the future, EISs on refuge plans offer opportunities to examine climate scenarios that might highlight the weaknesses of existing management authorities or the need for more far-reaching actions. The EIS process has already proved useful in forcing agencies and the public to consider impacts and actions outside the boundaries of their routine concerns. Agency responses to climate change may need to build on such institutional and educational opportunities. Although national level EISs have not yet addressed climate issues and implicitly assume the continuation of past climate patterns, they can consider climate impacts in the future. National refuge EISs should be evaluated to determine whether and how they might help FWS regions evaluate climate change data, formulate climate change scenarios, and assess the potential sensitivities of wildlife resources to global climate change. Individual refuge planning processes should be reexamined, and master plan/EIS processes may need to be resurrected in order to address climate impacts more effectively.

3.4 FEDERAL ACTIVITIES IN THE COASTAL ZONE

Sea level rise is a clear, easily understandable phenomenon that may accelerate over the next hundred years due to the warming effect of greenhouse gases. Seas around the world have risen about 12 cm over the past century. Recently the National Academy of Sciences posited three plausible scenarios for eustatic sea level rise to the year 2100, each involving increasing rates of rise as time goes by: 50, 100, and 150 cm (National Research Council, 1987). Within the next 25 years the highest sea level recommended for consideration would be 10 cm, but the rise will accelerate and may become increasingly significant with time. Actual sea level rise and its effects will differ widely from place to place, but resources of special concern include coastal structures with a life of more than 50 years and coastal wetlands.

The discussion below considers some recent examples of federal actions and long-range planning and EIS processes that relate to sea level concerns. Examples focus largely on coastal wetlands, which are jurisdictional concerns of several federal agencies.

3.4.1 Projects Affected by Sea Level Rise

Dramatic effects of coastal erosion over the past century are visible at Cape Hatteras, North Carolina, where the National Park Service recently wrestled with ways to save the famed Hatteras lighthouse from inundation, in part because of sea level rise of about one foot over the past 100 years. After preparing an EIS on alternative responses, the NPS concluded that a solution beyond 50 years required a closer look by the National Academy of Sciences. An NAS panel recommended moving the lighthouse inland rather than incur ever-higher costs for sea wall protection, in part because of rising sea levels. It had concluded that the shoreline in front of the lighthouse would retreat 157-407 feet by the year 2018, and 525-3,280 feet by the year 2088 (National Research Council, 1988).

Concern about rising seas prompted the Congress to authorize a Corps of Engineers' study on the implications for coastal flooding and erosion (1986 Water Resources Development Act, P.L. 99-662). Because study funds have not been appropriated, no study is under way. But Corps planners have analyzed sea level issues for specific projects, recognizing that local sea level problems depend on local coastal subsidence, sediment type, and tectonic forces. An example is the Hurricane Protection Project in the Mississippi delta, where subsidence and lack of accretion has made sea level "rise" 10 times more than the world wide average of one-half foot in the past century (Leatherman, 1987).

Case study: Corps construction project
The New Orleans to Venice, Louisiana, Hurricane Protection Project

Project purpose and history. This project, authorized by Congress in 1962, is intended to protect the developed area of Louisiana's delta plain southeast of New Orleans from hurricane tidal floods induced by subsidence, erosion, lack of accretion, and rising seas. The affected area lies along the Mississippi River in lower Plaquemines Parish. Annual land losses from several causes have amounted to about 200,000 acres, or over 1% of the region per year (U.S. Army Corps of Engineers, 1987).

The Corps proposed to increase the height of existing levees on the east and west banks of the river and modify current drainage facilities. The levees were intended to protect areas to the west from hurricane floods coming from the east. Levee construction on some reaches of the river began in 1968, before passage of NEPA.

The Corps completed a Final EIS on the proposed project in 1975, but environmentally preferable and less costly suggestions for a west-bank levee developed afterward, and some portions of the existing levee settled substantially. Hence the Corps decided to prepare a draft and final EIS supplement on the new proposals. The Corps filed a Final Supplemental EIS in November 1987, with an environmentally preferred and less expensive west-bank alternative.

The EIS does not take a long-range view of the development prospects and costs of the barrier measures proposed, and it does not explicitly address climate change issues. But the subject might just as well have been caused by climate change, because the EIS considers how to control a sea-level rise/subsidence/erosion issue of major concern to local citizens. As at Cape Hatteras and elsewhere, coastal land losses in Louisiana have become clear and threatening.

The EIS examined alternative responses: the costs of flood protection, the significant impacts of construction remedies, the effects on future development from doing nothing, and the somewhat greater development opportunities possible if flood barrier construction proceeds. In these respects the EIS focused its attention on significant public issues arising from sea-level rise.

3.4.2 Coastal Zone Management Act Programs

Significant losses of coastal wetlands will occur if sea levels rise substantially over the next hundred years. Even without subsidence, the National Academy sea level report notes the danger that "marsh grasses cannot accrete vertically fast enough to keep pace with sea level rise," putting extensive estuarine marshes in the United States at risk. Where uplands have been developed or bulkheaded, marshes will not be able to migrate shoreward as seas rise.

Federal programs under the Coastal Zone Management Act currently support the 30 approved state and territorial coastal programs with annual grants ranging from $0.5 to $2 million. These programs can be increasingly important in addressing the impacts of rising seas. NOAA's Office of Coastal Resource Management has influenced the content of these approved programs, and it helped stimulate Maine's decision to require that sea level rise impacts be taken into account in all state coastal permit reviews. The federal program continues to support studies of sea level rise, including a current study for New Jersey, New York, and Rhode Island.

Long-term preservation of coastal resources for scientific, economic, and environmental reasons is an option for state and local governments under the Coastal Zone Management Act. §315 provides for 50/50 federal matching grants to states for developing a national system of estuarine research reserves that represent the various regions and estuarine types in the U.S. Sites must provide opportunities for long-term research, education, improving coastal management techniques, and increasing public understanding of estuarine environments. EISs are prepared on these proposals, such as New Hampshire's Great Bay Estuarine Research Reserve, in 1987. Although these proposals and EISs have not included climate change issues in their rationale, they can provide strong scientific rationale for carrying out long-term research of coastal and related upland resources based on needs to preserve representative biogeographic estuarine regions. The EIS process requires federal, state, and local agency cooperation in assessing alternative planning approaches.

3.4.3 Long-Range Regulatory Planning Capabilities of Federal Agencies

Special Area Management Plans. Amendments to the Coastal Zone Management Act in 1981 encouraged the development of cooperative comprehensive planning by all levels of government for resource protection and economic development under a Special Area Management Plan (SAMP). The Corps of Engineers has articulated a related concept of a SAMP that it encourages through its §404 regulatory permit program (Regulatory Guidance Letter on Special Area Management Plans, October 1986).

The Coastal Zone Management Act amendments and the Corps program evolved from federal experience with the Grays Harbor development plan in the State of Washington. More than 10 years ago an Estuary Planning Task Force of local, state, and federal agencies began developing a management plan to reconcile demands for industrial development and wetland protection. Final approval of the plan still awaits final approval of the participating parties, although a final EIS has been completed under the Coastal Zone Management Act.

Despite delays, costs, and complexities of the Grays Harbor program, the Corps has encouraged Special Area Management Plans by its district commanders where sensitive environmental areas are under strong development pressure, a sponsoring local agency exists, public participation can be assured, and regulatory results would ease case-by-case permit reviews. The SAMPs under way or largely completed (for example, in Anchorage, Alaska) emphasize the need to integrate development planning with wetland protection.

Advanced Identification Program. EPA's Guidelines for §404 of the Clean Water Act allows EPA and the Corps of Engineers jointly to identify aquatic sites that are suitable or unsuitable for dredging and filling. This provision, §230.80, was added in 1980 to give the two agencies a new, flexible, nonregulatory mechanism to identify important or unimportant wetlands before developers apply for Corps' permits. It was originally intended to support comprehensive regional planning efforts by federal, state, and local agencies, such as the Grays Harbor estuarine planning program. In practice it has been used to gather data on, and inform the public about, critical wetlands in the Rainwater Basin, Nebraska, on Chincoteque Island, Virginia, within the Hackensack Meadowlands, N.J., in Southern Maine, in the Faulkner Lake region of Arkansas, and elsewhere. EPA believes that advanced identification can help all levels of government establish clearer wetland protection priorities, improve public and property owner understanding of wetland values, improve the technical information base of government agencies, and, ultimately, enhance wetland protection.

Case example: Areawide planning within the context of the Coastal Zone Management Act: the Hackensack Meadowlands

Local/Regional planning structure. No two areawide planning processes are alike, which makes the choice of one example difficult, but one of the most well known areawide development planning programs is New Jersey's Hackensack Meadowlands Development Commission. The HMDC was created by the State in 1968 to plan and carry out economic development, environmental protection, and waste disposal programs in 14 townships covering 20,000 acres of coastal wetlands and floodplains just across the Hudson River from Manhattan. Since then the HMDC has carried out environmental inventories and complex areawide planning, working to reduce conflicts between wetland protection and development. Substantial progress has been made in reducing water pollution and in improving the quality of many wetlands. Wetlands continue to be lost, however; the Giants' sports arena, for example, required substantial wetland filling.

Relation to federal programs. The HMDC Master Zoning Plan was approved in 1980 by the U.S. Department of Commerce as a part of the State Coastal Zone Management Program, but future permit applications to the Corps of Engineers for wetland development still had to be evaluated separately under the federal §404 program. When a development corporation sought Corps permits for a proposed a large industrial park development under the Master Plan, the EPA, FWS, and NMFS objected. After the Corps granted the permits and citizen and environmental groups sued the Corps and the developer, the federal court upheld the Corps and decided that an EIS was not required to address the proposal along with future development permit proposals.

Efforts to integrate the EIS process with revision of the Master Plan. Seeing a need for better understanding of the remaining 7,000 acres of wetlands in the District, EPA and the Corps, in cooperation with the HMDC, began an advanced identification program to identify wetlands suitable and unsuitable for being filled. The action to be addressed by the areawide EIS was whether or not the Corps should accept the Master Plan in deciding individual permit applications on a regional basis. Essentially the EIS was to provide a comprehensive means for federal agencies to assess data gathered by the federal advanced identification process and planning alternatives, including the proposed Master Plan of the HMDC.

Administrative problems with the EIS and planning process. The advanced identification and EIS process have not been carried out as planned, due to conflicts between the federal agencies and difficulties in merging federal work schedules with the tighter planning schedule of the HMDC caused early difficulty. Further questions arose over the appropriate geographic scope in the EIS for determining reasonable development site alternatives to the wetland proposals. The HMDC has favored restricting the inquiry to areas within its jurisdiction, whereas the federal agencies favor a look at site alternatives in a broader area.

The results illustrate the institutional barriers of concerns about agency "turf" and differences in agency missions, along with other bureaucratic difficulties, that can inhibit practical use of the EIS process in helping government agencies meet their planning and regulatory requirements.

Feasibility of applying the EIS processes to local development planning for coastal wetlands. Despite administrative problems, there are no inherent procedural barriers to the application of the EIS process to local areawide planning that cannot be overcome by agency decision makers; existing regulations need not be changed, and the EIS process can help areawide planning and decision making in coastal areas. In the Hackensack Meadowlands federal agencies have had a strong interest in the local plan for wetland protection. A process was begun under which important wetlands could be identified and incorporated into a revised areawide Master Plan. A federal EIS was envisaged to assess the revised plan and to consider approving it for purposes of issuing federal wetland fill permits under §404.

Although the HMDC is an unusual local planning agency because of its broad zoning and taxing powers, other areas have similar wetland planning problems and interests that EISs can also address. The administrative problems arising in Hackensack can be overcome in other places where local planning and federal regulatory actions interact. With strong policy guidance from headquarters, agreements are possible between federal agencies to tie federal advanced identification and other information-gathering efforts into existing local planning processes in ways that can avoid or reduce costly procedural conflicts.

3.4.4 Applicability of Federal Coastal Zone EIS Processes to Global Climate Issues.

Federal EISs in the coastal zone cover a wide range of actions, including federal land plans, funding for highway, sewer, and other infrastructure, land and water acquisition, public works construction, and regulatory actions. The National Academy report on responses to sea level rise over the next 100 years, and other estimates concerning coastal erosion over the next 30 to 50 years that may be developed by the Federal Emergency Management Agency, can provide a useful framework for EIS analyses of coastal plans and projects.

For coastal projects having a long life, or likely to influence development patterns over the long term, the three eustatic sea level changes up to the year 2100 can be considered as EIS scenarios. The following factors discussed in the NAS report are appropriate for such EISs routinely to consider within each scenario: the design life of proposed, affected, or induced facilities (most important if they would last more than 50 years); maintenance requirements from sea level rise; the degree of risk and magnitude of damage from sea level rise; site location alternatives; effects of protective measures on the natural and human environment; and the costs of preventing or retreating from sea level rise. These considerations can feasibly and usefully be applied to the EIS processes examined in this section of the report, but they will require additional, if modest, funds for EIS analysis.

Public works projects concerned with sea level rise. Site-specific EISs have already proved useful in assessing costs and impacts of proposals to prevent sea level rise through structures, beach enrichment, or other alternative nonstructural measures. In the future they offer important opportunities to focus public and agency attention on long-term effects of development decisions, including direct impacts of projects intended to last 50 years or more and indirect impacts of projects that may induce coastal development lasting at least as long.

Coastal zone management and natural resource protection programs. Rising seas put critical coastal ecosystems at risk. This situation should affect the priorities of federal programs for acquisition and protection of these ecosystems, including the estuarine research reserve program discussed above, and other programs of the National Park Service and Fish and Wildlife Service. These programs can use the EIS process to examine and explain the needs and opportunities to preserve biological diversity where rising sea levels may make future development costly. Requirements that EISs consider sea level rise and these resource impacts will force decision makers and the public to look beyond their noses, so to speak, when otherwise they might not.

Federal funding or permits for structures within the coastal zone must be consistent with approved State Coastal Zone Management Plans. Plans can be amended to address future problems of sea level rise. EISs on federally aided highways, sewage treatment plants, and other actions will need to give increasing consideration to sea level rise impacts and to the scenarios and factors discussed in the NAS report.

Wetland regulatory programs. Sea level rise has not significantly affected wetland regulatory actions along the coast, but this situation may change. In coastal as well as inland areas, federal programs to identify and/or regulate important wetlands can and should be integrated into local planning processes. As in the case of the

Trinity River comprehensive EIS, areawide EISs in the coastal zone can help local and federal agencies evaluate long-term options for wetland protection on a comprehensive rather than a piecemeal basis.

Areawide regulatory EISs can and should evaluate how the three sea level rise scenarios might affect important wetlands over the next hundred years. Maps showing areas that may be threatened by coastal erosion over the next few decades will greatly facilitate this analysis. Among the long-term issues to address under each scenario are the following: opportunities and needs for upland protection to allow natural migration of wetlands as seas rise; increased coastal flooding effects and needs for wetlands to contain floods; long-term impacts of wetland losses on migratory birds; and mitigation actions appropriate to protect wetlands over time.

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APPENDIX

Federal Programs Related To Long-term Climate Change

Department of Agriculture

Agriculture Stabilization and Conservation Service

Water Bank Program. Direct payments for 10 year contracts with landowners for migratory waterfowl habitat protection. Wetland protection coordinated with Fish and Wildlife Service and states. 16 USC 1301-1311.

Agricultural Conservation Program. Cost-share assistance for habitat conservation, erosion and sediment control, point and non-point source pollution, energy conservation in accordance with specified standards through contract and easements with landowners. 16 USC 1501-1501.

Emergency Conservation Program. Direct cost-sharing payments to farmers for new emergency conservation measures to control wind erosion or to rehabilitate farmland damaged by drought, floods, wind erosion, or other natural disasters. (Available in Puerto Rico, Virgin Islands.) 16 USC 2201-2205.

Conservation Reserve Program. Direct payments to eligible owners of highly erodible land under 10 year contracts for implementation of programs to plant trees, grasses, other vegetation. P.L. 99-198.

Farmers Home Administration

Soil and Water Loans. Loans to eligible farming enterprises for soil conservation, water development, forestation, drainage, pollution control, energy conservation. (Applicable to Puerto Rico, Virgin Islands, Guam, American Samoa, Northern Mariana Islands.) Repayment of up to 40 years. 7 USC 1922-28.

Watershed Protection and Flood Prevention Loans. Loan funds for municipal corporations, soil conservation districts, other not-for-profit groups, for flood prevention, irrigation, drainage, sediment control, water based recreation, fish and wildlife development. P.L.93-566, P.L. 78-534.

Forest Service

Cooperative Forestry Assistance. Grants to state forestry programs for private, state, local, forestry activities. P.L. 95-313.

Forestry Incentives Program. Cost-sharing payments for increased tree production to owners of non-industrial private forest lands of 1,000 acres or less with approved forest management plans in FIP designated counties. Approximately 5,000 recipients covering nearly all states. P.L. 95-313.
Renewable Resources Planning Act. Assessment of all renewable resources for forest and range lands every 10 years, and a long range plan/EIS every 5 years. 16 USC 1600-1614.

Land and Water Conservation Fund. At least 40% of this fund is allocated to federal land management agencies for purchase of outdoor recreation areas. 16 USC 4601-4 to 4601-11.

National Forest Planning. Requires comprehensive plans, to be reviewed every 10 to 15 years, for each national forest to meet multiple uses. National Forest Management Act of 1976.

Rural Electrification Administration

Rural Electrification Loans. Long-term loans to rural electric cooperatives, public utility districts, municipalities, and other qualified applicants for supply of electricity to rural areas. 7 USC 901-916, 930-940.

Soil Conservation Service

Great Plains Conservation. Direct cost-sharing payments to landowners in one of the 519 designated counties in Great Plains for soil and water conservation necessary to protect farms against climatic and erosion hazards. Contracts with landowners for 3 to 10 years. Public Laws 74-46, 84-1021, 86-793, 91-118, 96-263.

Rural Clean Water Program—cost sharing contracts with landowners of 5-10 years for Best Management Practices under approved 208 plan.

Resource Conservation and Development. Grants to states, localities, and non-profit organizations authorized to plan and implement resource conservation and development programs. Grants are for planning and installing projects for flood prevention, sediment and erosion control, water-based recreation, agricultural pollution control. Public Laws 74-46, 75-210, 89-796, 87-703, 91-343, 92-419, 97-98.

Rural Abandoned Mine Program. Direct cost-sharing grants to private owners of abandoned coal lands for conservation, reclamation and development of soil, water, woodland, wildlife, recreation resources. 30 USC 1236.

Small Watershed (PL-566) Program. Technical and cost sharing to states and localities for planning, designing, installing watershed improvements, flood prevention, irrigation, drainage, sediment control, water-based recreation. P.L. 83-566 as amended; 43 USC 422a-422h.

Soil and Water Conservation. Technical assistance to individuals and groups to plan and apply soil and water conservation measures. Nationwide application with annual services to approximately 1 million landowners and 30,000 government units. P.L. 74-46.

Soil and Water Resources Conservation Act (RCA) Program. This act requires the Department of Agriculture to undertake (in 1980, 1985, and every ten years thereafter) an appraisal of, and program, for soil, water, and related resources affecting the 1.5 billion acres of U.S. private land. The RCA program must include regular monitoring the current state of the resource base, projections of future demands for food and fiber, and review of conservation policy choices in detail. The purpose is to encourage landowners and farm operators to conserve soil, wildlife, and energy resources while meeting demands for basic foodstuffs. 1977 Soil and Water Resources Conservation Act (P.L. 95-192).

Wetland Conversion ("Swampbuster"). The Food Security Act of 1985 (Title XII C) makes farm operators ineligible for price-support payments, and insured or guaranteed loans for any year in which an annual crop was produced on converted wetlands, which are defined in the Act. (P.L. 99-198.)

Department of Commerce

Economic Development Administration

Economic development. EDA administers grant programs for public works, business development, technical assistance, public works impact projects, and state and local economic development planning. Public Works and Economic Development Act of 1965 (42 USC 3131 et seq.).

National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Zone Resources

Coastal Zone Management Act. The Act provides grants for state (including Puerto Rico, Virgin Islands, Guam, American Samoa, Northern Marianas, and Trust Territories') coastal zone management programs, including planning for impacts of offshore energy development, and information on coastal resources and hazards. Coastal Zone Management Act of 1972, as amended, 16 USC 1451 et seq.

Estuarine Sanctuary Program. Matching grants are provided to states for acquiring, developing and operating national estuarine sanctuaries. 16 USC 1461.

Marine Sanctuary Program. Provides for designation of marine areas a sanctuaries to conserve multiple resource values. 16 USC 1431-1434.

National Marine Fisheries Service

Anadromous and Great Lakes Fisheries Conservation. Federal funding is available for research, and improvements of spawning and other fishery structures to conserve and enhance anadromous fish resources. The program is administered in cooperation with the U.S. Fish and Wildlife Service. Anadromous Fish Act of 1965, 16 USC 757a.f.

Department of Defense

Army Corps of Engineers

Regulatory Program. The Corps of Engineers must issue permits for activities affecting discharge in or obstruction to U.S. waters or for activities affecting navigable waters of the U.S. 33 USC 1344 (§404 Clean Water Act of 1972, as amended), 33 USC 401, 403, 404, 406, 407 (Rivers and Harbors Act of 1899).

Beach Erosion Control Projects. To control beach and shore erosion of public shores the Corps of Engineers designs and constructs projects not specifically authorized by Congress if nonfederal sponsoring agencies assume responsibilities for project costs, maintenance, public access, and water pollution control. 33 USC 426g.

Flood Fighting and Rescue Operations, Emergency Protection of Coastal Protective Works, and Emergency Rehabilitation (Public Law 84-99) Program. Assistance is provided for emergency repair or rehabilitation of flood control works damaged by floods, wave action, and assistance in flood fighting and rescue operations. Flood Control Act of 1941, as amended, 33 USC 701n.

Small Flood Control Projects and Small Navigation Projects. The Corps of Engineers designs and constructs projects for which nonfederal sponsoring agencies assume responsibilities for project costs, maintenance, and public assess. 33 USC 701s, and 33 USC 577.

Planning Assistance to States. The Corps provides funds for comprehensive state plans for development, use, and conservation of water and related land-use resources in drainage basins. Water Resources Development Act of 1974 (§22), 42 USC 1962d-16.

Congressionally Authorized Water Resource Development. Specific project design and construction in accordance with specific congressional legislation. Congress authorized and funded forty-one new Corps and BuRec projects under new cost sharing arrangements with non-federal entities. P.L. 99-88.

Department of Energy

National Energy Policy Plan. The President is required to prepare and submit to Congress, biennially, a National Energy Policy Plan that (a) considers energy objectives for periods of 5 to 10 years, with particular attention to employment, price, security, environment, growth, nuclear proliferation issues; (b) identifies strategies to achieve objectives, including the level of conservfation and investment that is necessary; (c) evaluates current and foreseeable trends in energy use and management and the social, environmental, and economic effects of such trends. (§801, Title VIII, Department of Energy Organization Act, P.L. 95-91, 42 USC 7321).

Nuclear Waste Disposal. The Department of Energy is responsible for identifying and planning suitable sites for long-range disposal of spent nuclear fuel and hi-level nuclear wastes in geological repositories. Twelve sites were proposed for consideration in 1986 for public consideration. Nuclear Waste Policy Act, 42 USC 10101 et seq.

Conservation and Renewable Energy

State Energy Conservation. Grants to states for development, implementation , or modification of a state energy conservation plan submitted to and approved by DOE. Each plan must contain five program measures required by statute. Energy Policy and Conservation Act, Title III, §361-366, 42 USC 6321-26, and National Energy Conservation Policy Act, P.L. 95-619.

Energy Extension Service. Grants to states and territories to encourage individuals and small establishments to conserve energy and convert to alternative energy sources. 42 USC 7101.

Energy Conservation for Institutional Buildings. Grants to non-profit institutions and local governments for help in acquiring and installing energy conservation measures. 42 USC 6371.

Conservation Research and Development. Project grants for long-term efforts to develop and transfer to the private sector various energy conservation technologies. Department of Energy Organization Act, P.L. 95-911, and P.L.'s 97-377, 98-50, 98-146.

Industrial Energy Conservation. Project grants to increase industrial energy use efficiency and to promote substitution of renewable fuels for scarce fuels. P.L. 95-911 and Interior Department and Related Agencies appropriation acts.

Fossil Energy

Coal Loan Guarantees. Guaranteed loans to medium sized operators to finance development of new underground coal mines, expansion of existing mines, and construction of coal preparation plants that will reduce sulfur content. Energy Policy and Conservation Act, P.L. 94-163; Energy Conservation and Production Act, P.L. 94-395; Power Plant and Industrial Fuel Use Act of 1978, P.L. 95-620.

Fossil Energy Research and Development. Project grants for support of long-term, high risk r&d to increase domestic production of oil and gas or shifts to more abundant coal and oil shale resources.

Clean Coal Initiative. Project support for competitive solicitations proposing clean coal technological innovations. (Specific congressional authorizations for program.)

Intergovernmental Relations

Indian Energy Resources. Technical assistance to Indian tribes to encourage development and good management of Indian owned energy and environmental resources. P.L. 95-911.

Bonneville Power Administration

Planning, operation, and management of the Bonneville Power Administration, including long-range planning for electric power generation, transmission, marketing, use and conservation in the Northwest, and including river basin studies. 16 USC 832-839.

Environmental Protection Agency

Office of Air

EPA programs for: approval and enforcement of State Implementation Plans, establishment of national emission standards for hazardous air pollutants, new source performance standards, regulations concerning proper emission stack heights, stratospheric ozone protection research and cooperation, motor vehicle fuel standards, establishment of ambient standards, emission standards for mobile sources, fuel economy standards for automobile manufacturers' fleets. Clean Air Act, 42 USC 7401-7642, and Energy Policy and Conservation Act, 15 USC 20003(d).

Office of Water

EPA programs for: establishing water quality standards, NPDES permits, §404 dredge and fill permits, waste water treatment construction grants , estuarine management, non-point pollution, designation of sole source aquifers, ground water protection, underground injection control. Clean Water Act, as amended, and Safe Drinking Water Act of 1974, as amended.

Office of Research and Development

Research programs on: air pollution control, pesticides, solid waste disposal; water pollution, safe drinking water, toxic substances.

Federal Emergency Management Administration

National Flood Insurance Program. Provides federally-subsidized flood insurance against loss of real or personal property from floods, according to community land use regulations meeting federal standards. National Flood Insurance Act of 1968 and Food Disaster Protection Act of 1973, 42 USC 4001-4128.

Federal Energy Regulatory Commission

Hydroelectric Power Licensing. Licenses must be approved by the FERC for private hydroelectric projects on U.S. navigable waters. Existing projects must be approved for relicensing. Federal Power Act of 1922, as amended.

Natural Gas Pipeline Certification. The FERC must approve certification of interstate natural gas transportation systems. 15 USC 717, 3301-3432.

Department of Housing and Urban Development

Solar Energy and Energy Conservation Bank. Grant incentives for individuals, non-profit groups, for purchase and installation of energy conservation and solar energy measures. Energy Security Act, 12 USC 3601.

Department of the Interior

Office of Surface Mining

Regulation of Surface Coal Mining and Reclamation. Establishment of standards for federal coal surface mining (including hydrological impacts and reclamation and revegetation requirements) and for state coal surface mining under the federal program. 30 USC 1232 *et seq.*

Fish and Wildlife Service

Endangered Species. Programs for listing threatened and endangered species, analyzing impacts of federal and private actions affecting such species, preparing and carrying out species recovery plans, preparing habitat conservation plans for incidental takings and issuing permits for takings. 16 USC 1531-1543.

National Wetlands Inventory Project. Program classifies, identifies, and maps wetlands for data base to aid management and regulation. 16 USC 661-666c.

Migratory Bird Program. Program for the inventory of significant waterfowl habitats and purchase in fee or easement. 16 USC 718.

Emergency Wetland Resources Act Program. Establishment of priorities for wetland acquisition by states and federal government. Emergency Wetland Resources Act of 1986.

Pittman-Robinson and Dingell-Johnson Acts. Program allows grants in aid to states for habitat and species restoration. 16 USC 669-91, 777-777k.

National Park Service

Coastal Barrier Resources Act Programs. This program bars use of federal financial assistance on coastal barrier islands delineated on official Coastal Barrier Resources maps. The program now encompasses 187 units of barrier islands. Coastal Barrier Resources Act of 1982, P.L. 97-348.

National Park Master Plan Program. Program for establishing Master Plans for each National Park to maintain and enhance National Park System. 16 USC 1-3, 461.

Bureau of Land Management

BLM Land Use Planning Program. Land use planning programs for BLM units, and Habitat Management Plans for wildlife habitats on public lands. 43 USC 1701 et seq.

Minerals Management Service

Federal Coal Leasing Program. Management of federal coal leasing under criteria established by the Mineral Leasing Act of 1920 as amended. BLM actions include establishment of leasing schedules, development of criteria for determining commercial quantities required for production, criteria for relinquishing leases, diligence requirements, royalty requirements. 30 USC 201 *et seq.*

Outer Continental Shelf Leasing Program. Leasing of oil and gas and other mineral in US waters over continental shelf. A five year leasing plan is required. Outer Continental Shelf Leasing Act, as amended.

Bureau of Reclamation

Reclamation Act Program. Construction and operation of irrigation, flood control and power projects in 17 western states. 43 USC 411 et seq.

Bureau of Outdoor Recreation

Outdoor Recreation Program. BOR reviews and approves State Outdoor Recreation Land and Water Recreation Plans for the protection and acquisition of wetlands, open space, and other land and water resources necessary for active and passive recreation. 16 USC 4601-4 to 4601-11.

Geological Survey

Survey Program. Collection and analysis of data on land use. Various authorities.

Department of State/Agency for International Development

Foreign Assistance Program. AID programs have an increasing focus on natural resource conservation, including coastal zone management assistance (Ecuador, Sri Lanka, Thailand), energy conservation, water resource use and development. Foreign Aid Assistance Acts.

Tennessee Valley Authority

Programs for electric power generation, flood control, recreation, fertilizer development, economic development, natural resources development, and valley agricultural development. Tennessee Valley Authority Act of 1933, as amended. 16 USC 831 *et seq.*

Department of Transportation

Federal Aviation Administration

Airport Improvement Program. Grants to states, counties, municipalities, and other public agencies for planning, constructing, improving or repairing a public-use airport. Federal cost sharing varies for various parts of an airport project, including noise controls. Airport and Airway Improvement Act of 1982, as amended, P.L. 97-248, and P.L. 96-193.

Federal Highway Administration

Highway Planning and Construction Program. Grants in aid to states for construction and rehabilitation of interstate and other highways. Title 23 USC, "Highways" as amended P.L. 97-424 and 98-229.

U.S. Coast Guard

Bridge Permit Program. Requires permits for all bridge projects over navigable waters. 33 USC 3525.

Federal Railroad Administration

Railroad Rehabilitation and Improvement. Financial assistance for acquiring or rehabilitating and improving railroad facilities, or for developing new railroad facilities. 45 USC 831.

Urban Mass Transportation Administration

Programs for capital improvement grants, research and training, and managerial training grants for urban mass transportation. Urban Mass Transportation Act of 1964, as amended, 49 USC 1601 *et seq.*

Nuclear Regulatory Commission

Nuclear plant licensing. Licensing of nuclear power plants and monitoring of safety and other requirements. Atomic Energy Act of 1954, as amended, 42 USC 2021.

CLIMATE CHANGE AND WATER RESOURCES IN THE SACRAMENTO-SAN JOAQUIN REGION OF CALIFORNIA: POLICY ADJUSTMENT OPTIONS

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FINDINGS[1]

The Sacramento-San Joaquin region of northern California is particularly vulnerable to changes in precipitation and temperature that might result from the greenhouse effect (or natural climate change) because of the critical role that water development has played in the region's economic development. Three key water management issues are especially sensitive to climate change: (1) water supply and flood control; (2) land use and levee maintenance in the Sacramento-San Joaquin Delta; and (3) water quality in the Delta. This study could find no instance in which public policies and plans addressing these issues explicitly take account of the potential for future climate change.

WATER SUPPLY

Water supplies in the California State Water Project (SWP), which provides users ranging from small irrigation districts to metropolitan Los Angeles, are sensitive even to small changes in runoff owing to the close balance between current demand and supply. In addition, demand is projected to double over the next two decades. The federal Central Valley Project (CVP), the nation's largest irrigation system, also in the same basin, is less sensitive because of excess capacity.

SWP managers have responded to recent climate fluctuations and the project's heightened climate sensitivity by adopting more flexible operations, including accepting greater risk of failing to meet original firm yield targets in some years. This adjustment strategy began to emerge in the mid-1970s as the development of planned major facilities (e.g., additional onstream storage and a Delta transfer canal) was delayed by environmental concerns and the changing economics of public investment (i.e., altered federal/state cost-sharing formulae). Project managers responded to recent climate extremes by first implementing rigid, and then more flexible, allocation rules that allow the reliability of supply and supply projections to vary according to climate conditions. Whether such flexible operational adjustments can accommodate impacts from cumulative climate change is difficult to assess. However, constraints on the development of new facilities like reservoirs means that climate change will create greater pressure to find alternative ways of maintaining the reliability that insulated users from past climate fluctuations.

In the latest update of the State Water Plan, project managers predict they will not meet near-future demands without additional structural and operational changes, even if climate is stable. Among the adjustments suggested to bridge this gap are an offstream storage reservoir south of the delta (a configuration likely to receive less adverse environmental reaction than previously proposed big reservoirs), increased sharing of CVP water, and improvements in Delta conveyance facilities. Yet, even these developments will only maintain a rough balance between demand and supply, and climate change, which was not explicitly addressed in the Plan, could further lessen the likelihood of meeting projected demand.

Under the current conditions of closely balanced supply and demand, water supply reliability and flood safety are countervailing goals in the Basin: attempts to increase one usually reduce the other. This represents a potentially serious policy conflict between agencies and resource management goals. Recent climate impacts suggest that relatively small future changes in runoff could require changes in flood protection policies that reduce freshwater yield--and vice versa. Simulation studies indicate that a slightly earlier runoff due to warmer temperatures could markedly reduce the likelihood of meeting reservoir storage goals in most years. Feasible changes in flood control rules are not sufficient to ameliorate this impact. This will heighten the tension between flood management, which is chiefly a federal responsibility, and water supply, which is managed at all governmental levels, and may pressure planners into traditional adjustments like new reservoir construction.

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The theoretical range of options for adjusting supply and flood control extends from the traditional approach of building more and larger facilities, to a set of institutional and behavioral adjustments that reduce the demand for water and/or encourage reallocation between competing uses. Calls for additional storage in the basin illustrate the former option, while the recent agreement for coordinated operation of the SWP and CVP provides an innovative example of the latter. Project coordination and sharing is innovative because water systems are traditionally operated in isolation; similar adjustments are beginning to appear in other climate-sensitive regions of the country (e.g., the Potomac Basin). How much "absorptive capacity" such operational adjustments provide in relation to cumulative climate change remains to be assessed.

DELTA ISLAND MAINTENANCE

The climate threat to the Sacramento-San Joaquin Delta also raises a wide range of theoretically feasible responses, from a commitment to physical protection at any cost ("maintaining the status quo") to allowing the Delta to metamorphose into a brackish marsh (a policy of "strategic inundation"). There exists large institutional and economic momentum to maintain the Delta islands as currently configured, despite threats from land degradation and substances, reduced runoff, and sea level rise. Three preconditions for large public investment in maintaining the Delta in the fact of climate threats are in place: A philosophical and popular political rationale, a policy mechanism for public investment (the Delta Levees Maintenance Subvention Program), and the tools for fighting climate impacts (e.g., permits and engineering strategies). Thus, efforts to combat climate-induced degradation of the Delta through large public investment and structural solutions, rather than to accept significant changes in land use, are likely to dominate future responses.

Water quality protection in the Sacramento-San Joaquin Delta has begun to take precedence over water supply concerns in the policy arena. Delta water quality standards are defined in detail by state legislation and backed by federal law, whereas water supply reliability criteria are not as explicit in current water development plans, nor are they guaranteed by legislation. Thus, quality maintenance policies are likely to worsen the water supply problem under a growing climatic constraint on supply. The range of adjustment options in the face of climate change that reduced runoff includes accepting lower Delta water quality or reducing the upstream water uses (especially in the CVP and SWP). One mechanism for adjusting Delta water quality policy, the current interagency "Bay-Delta Hearing", could yield different (probably stricter) standards over the next few years, giving water quality even greater priority. However, the Bay-Delta Hearing will probably not be completed for several years.

POLICY IMPLICATIONS

The proliferation of interests and institutions focused on parts of what is, essentially, a connected constellation of climate-sensitive policy issues in Northern California, suggest that near-future climate change could create new ties between resource management areas, as well as new tensions. The coordinated operations agreement between the SWP and CVP represents a major policy adjustment to environmental uncertainty (e.g., variable and likely increasing requirements for carriage water to maintain water quality in the Delta, and short-term climate fluctuations). It could act as a model for adjusting policy to other impacts of climate change. Indeed, additional interagency cooperation has been proposed in the state's latest water planning document, but no strategy has yet emerged to offer an integrated response to the interacting problems of supply, flooding, quality, and Delta protection, which could be exacerbated by almost any nontrivial magnitude or direction of climate change. Perhaps a new form of integrated regional planning, based on climate sensitivities, is needed given to deal with the emerging threat of climate change.

CHAPTER 1

INTRODUCTION

This report examines some of the options for adjusting water resource management policies in the face of potential future climate change in California's Sacramento-San Joaquin region. We analyze the current policy landscape (the institutions and issues involved and the social mechanisms available for adjustment), examine responses to recent climate impacts, and describe a range of potential adjustments in the face of a climate change that would affect water-related resources in the area.

THE THREAT OF CLIMATE CHANGE

Global climate warming predicted to accompany increasing atmospheric concentrations of greenhouse gases has become a major national and international policy issue. Increasingly credible predictions indicate that anthropogenic climate changes are likely to emerge from the noise of natural climate variability during the next decade or so. By the middle of the 21st century, global average temperatures may be 3°C to 5°C warmer than present (World Meteorological Organization, 1985; National Academy of Sciences, 1983). Some analysts believe that global warming is already under way (Hansen et al., 1988, 1988; Hansen and Lebedeff, 1988), as evidenced by unusually warm temperatures in the 1980s.

In concert with increasingly reliable predictions of climate change, our ability to assess their impacts has improved (Kates et al., 1985). Researchers have studied historical climate-society relationships (Parry, 1981; Bowden et al., 1981), assessed international implications of climate impacts (Kates, 1980), and predicted climate change impacts on agriculture (Parry et al., 1988), global food supplies (Liverman, 1987), water resources (Hanchey et al., 1988), and other natural resource areas.

These impact studies point to disruptive and potentially irreversible climate change effects on natural and social systems (Parry et al., 1988). The U.S. Environmental Protection Agency's report to Congress, the most comprehensive assessment of nationwide impacts to date, indicates how pervasive and far-reaching climate change effects could be: affecting water and food supply, land use, energy demand, air quality, health, and essentially all other economic sectors. Moreover, serious impacts may be associated with even the more modest climate changes likely to occur well before the oft-cited benchmark of doubled greenhouse gas concentration is reached during the mid-21st century.

Impact projections have led to calls for concrete policy actions (White, 1988). Proposed responses are aimed mostly at reducing anthropogenic greenhouse gas emissions in order to prevent, or at least delay, global warming (Conference Statement Committee, 1988). Much less attention is given to the question of how well systems for managing climate-sensitive resources can cope with climate change. Yet global warming in the range of 1° to 2°C is likely to occur in the next two decades even with immediate greenhouse gas emission reductions, as accumulated gases and thermal inertia in the atmosphere-ocean system conspire to raise global temperature (Jones et al., 1987). Resource managers may thus have to adjust to noticeable climate shifts in the near future, although the regional pattern of these changes cannot yet be predicted with much certainty.

ADJUSTING TO CLIMATE CHANGE

At the most abstract level, there are essentially two types of human responses to climate change: inadvertent and purposeful. Even without recognizing that the climate is changing, people and institutions will adjust inadvertently, through existing mechanisms. Changes will occur in how people manage water, forests, agriculture, and other climate-sensitive resources, even in the absence of climate change adjustment policy _per se_. Indeed, some researchers argue that inadvertent adjustment can, in most cases, absorb the impacts of the greenhouse effect with little or no social disruption. Others argue that the scale and magnitude of potential greenhouse climate changes are such that severe social impacts can only be avoided through purposeful planning and anticipatory policies.

At least in the near-term--over the next two decades or so--the most likely policy responses will be inadvertent, incidental, and reactive. Climate fluctuations that are either part of normal climate, or of the greenhouse effect (there will probably be no sound scientific basis for distinguishing between these two over the next several years), will elicit policy responses either by tripping existing response mechanisms like flood control plans and crop damage payments, or by eliciting emergency response geared to extreme events. Thus, there is reason, in any impact assessment, to examine existing policy mechanisms and contemporary trends which affect social adaptability.

More purposeful adjustment will emerge only with strong belief among decision-makers that the climate will change in the future or that climate change is actually under way. Purposeful adjustment policy might take four general forms:

do-nothing: recognize the change but take no action.

laissez-faire: let systems adjust without assistance.

reactive: establish or fine-tune mechanisms as impacts accumulate and adaptive pressures build, but take no action now.

proactive: begin a phased adjustment of resource systems now to absorb climate change.

These adjustment categories overlap, of course, and different policy mixtures will come into play in a changing climate. For example, some economic areas may simply be left to adjust without government assistance, while in other cases the threat to social well-being may be so great that active public policy intervention is called for. Both inadvertent and purposeful adjustment might proceed either incrementally or as a series of crisis responses.[2] Resource managers might, for instance respond to climate change gradually by adjusting resource systems in small steps, or by responding chiefly to the most severe impacts or to surges of new information or dire predictions.

THE CASE OF CLIMATE CHANGE AND POLICY IN CALIFORNIA

The goal of this study is to identify policy elements that may affect response to climate changes in California's Sacramento-San Joaquin region (Figure 1). The focus is on issues raised by climate change in terms of water resource impacts, the public and private institutions likely to play a role in adjustment (Table 1), and the theoretical and practical range of adjustments available to resource managers. Thus, this analysis does not include more speculative responses such as wholly new public programs aimed at stabilizing climate or the restructuring of resource management systems in fundamental ways. Resource management theory suggests that decision-makers in an area affected by climate change will first rely on existing mechanisms, traditional approaches, and least-cost options as they respond to impacts, and will be slow to recognize and accept the need for more far-reaching change. Thus, our analysis points out policy responses that might emerge over the next several years while the climate future remains uncertain, but public pressure to mitigate future impacts grows.

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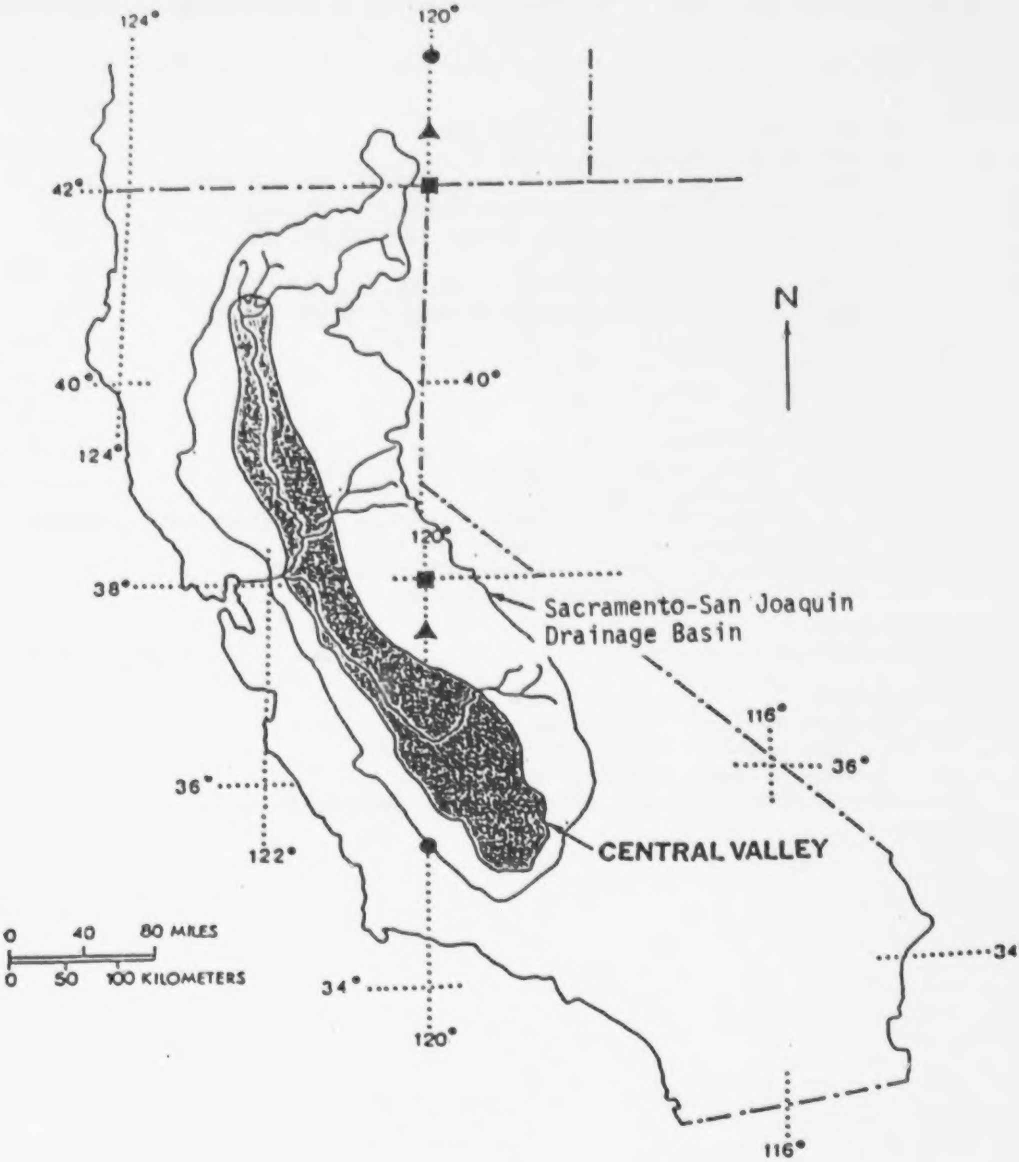
[2] This distinction was drawn by political scientist M.H. Glantz (1979) to illustrate the different responses likely to emerge if planners view CO_2-induced climate change as a slow, cumulative trend vs. a disjunct, step-like process (e.g., if they focus on a doubling of CO_2).


124°
120°
42°
N
40°
40°
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120°
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Sacramento-San Joaquin
Drainage Basin
116°
36°
36°
122°
CENTRAL VALLEY
0 40 80 MILES
0 50 100 KILOMETERS
34°
34°
120°
116°

Figure 1. California's Sacramento-San Joaquin Basin.

Table 1. Institutions Most Likely to Play a Role in Responding to Climate Change in Northern California

- U.S. Army Corps of Engineers - (FC, ER)
- U.S. Bureau of Reclamation - (WS)
- Federal Emergency Management Agency (FEMA) - (FC, DL, ER)
- State Federal Resource Control Board (SWRCB) - (WS, WQ)
- Department of Water Resources (DWR) - (WS, FC, DL, ER)
- The Reclamation Board - (FC, DL)
- Office of Emergency Services (DES) - (FC, DL, ER)
- Bay Conservation and Development Commission (BCDC) - (LU)
- California Department of Fish and Game -(REC)
- Suisun Resource Preservation District (LU)
- State Water Contractors - (WS)
- State Lands Commission - (LU)
- Delta Municipalities - (LU)
- Delta Advisory Planning Council (DAPC) - (FC, LU)
- Local Reclamation Districts - (DL)
- Bay Institute, Environmental Defense Fund, Other Non-governmental Organizations - (NGO's)
- East Bay Municipal and Utility District (WS, WQ)
- Metropolitan Water District of Southern California (WS)
- Association of California Water Agencies (WS)

Key to table codes:

WS - water supply
FC - flood control
LU - land use/zoning
RE - recreation
WQ - water quality
DL - delta levee maintenance
ER - emergency response
NG - non-governmental organizations

CHAPTER 2

THREE WATER RESOURCE POLICY PROBLEMS IN CALIFORNIA

Though climate pervades essentially all social and economic aspects of water resources in the region, future policy response will probably focus on three areas particularly vulnerable to climate change:

(1) Water supply management:

This represents a central and linking issue in California, where water supply is the basis for most economic development: agricultural, industrial, recreational, etc. Water binds together climate, other natural resources, and society. The chief problem here is to accommodate rising demand, short-term climate fluctuations, the need to export water from the water-rich north to southern California, flood hazard mitigation, and the potential for long-term climate change.

(2) Delta islands land use and maintenance:

The delta at the confluence of the Sacramento and San Joaquin Rivers acts as the focus of water supply, wetland habitat, and other environmental protection issues, and represents a critical natural hazard and land use problem centered on protecting areas threatened with inundation. Much of the land, the so-called Delta islands, is protected by a system of levees of various ages and reliabilities. Devoted mainly to agriculture, the Delta islands are also very important in helping prevent salt water intrusion into the river system. Subsidence of the islands below sea level has led to an increasing rate of levee failure in recent years, and sea level rise or changes in quantity and/or timing of freshwater runoff would exacerbate this problem.

(3) Water quality:

Another major component of the "Delta problem" relates to the intrusion of saline waters eastward from San Francisco Bay into the riparian system owing to four factors: levee deterioration, freshwater consumption and transfer above and within the Delta, short-term wind surge, and sea level rise. This issue is intimately related both to water supply and Delta levee maintenance.

Of course, there are other resource management issues in the region that will likely prove sensitive to climate change, including the estuarine functions of San Francisco Bay and bay-shore land use, forestry, dryland agriculture, recreation, transportation, and energy use. But the pivotal importance of water development, plus the ability to model the cascade of impacts associated with runoff in a credible way, makes water a logical focus for an initial impact assessment.

The goal of this report is not to prescribe response policy. The policy implications raised here are meant to guide later analysts who will translate better predictions of climate change and impacts into policy responses if a consensus emerges, owing to new predictions or to actual climate impacts, that climate change warrants overt public policy response.

WATER SUPPLY MANAGEMENT

The underlying challenge in managing California's water resources is the natural spatial and temporal maldistribution of supply and demand in the state. More than two-thirds of the state's surface water supply originates north of about Sacramento, while 70% of the state's population and 80% of the total demand for water lie to the south. Another problem is the seasonality of runoff: most of the runoff occurs during November-April while peak demand occurs during June-August. Finally, as population has grown, demand has increased. Subsequently, supply reliability has been stressed in some areas, while conflict over use and allocation is growing in others. The study areas is also subject to flooding during the runoff season, and substantial public investment has been devoted to flood control, especially along the American River near Sacramento.

Water resource management policy in the region has been changing over the last decade, and California is today at a critical juncture in water development that makes the region particularly sensitive to climate uncertainty. The salient management change has been a swing away from building large storage and conveyance facilities, to more flexible and efficient operations of existing facilities. Wolman and Wolman (1986) observed that this trend is evident throughout the country. In California, environmental and economic factors have slowed the development of physical facilities over the past decade, reducing the buffer of "excess" capacity and creating marked water supply and flood control vulnerabilities to climate and other perturbations.

The Policy Environment of Water Supply

Northern California's Sacramento-San Joaquin Basin is the setting for two of the largest and most elaborate water management systems in the world: the Bureau of Reclamation's Central Valley Project (CVP), and the State Water Project (SWP) planned and operated by California's Department of Water Resources (DWR). These two agencies lie at the focus of a complex set of social institutions including the water users (ranging from small irrigation companies to the Metropolitan Water District, which has call on almost half of the SWP's total supply for delivery in southern California), other state and federal agencies with regulatory power over water-related issues (e.g., the Corps of Engineers, which sets flood control policy, and the State Water Resources Control Board (SWRCB), which regulates water quality and sets water rights), and environmental advocacy groups, which are particularly powerful and visible policy players in California.

The Key Issue is Long-term Water Supply Adequacy

Both the CVP and SWP employ large surface water storage to capture winter and spring runoff for use during the summer peak demand period. Elaborate systems of canals, aqueducts, pumping plants, and other control structures deliver water to agricultural, municipal, and industrial users.

The foremost concern vis-a-vis climate change is the system's overall adequacy in the face of changes in total runoff or its timing. The SWP's supply reliability is defined in its statutes and contracts with users as the ability to meet requests in all but the most "extraordinary conditions." Until 1977, this reliability was supported by a large buffer between supply and delivery (Figure 2), which not only assured long-term supply but made seasonal deliveries more reliable. If the rains stopped late in the wet season, managers could still meet projected demand by drawing on the large buffer supply.

Because the project was in many respects a response by the state legislature to severe drought in 1928-34 (when the need for drought-proofing was first voiced), managers acted very conservatively, tending to treat every dry spell as if it were a recurrence of this historical event. Thus, the worst drought on record became the project's design target, a water planning for such multiple-year droughts was further supported by the occurrence of several back-to-back dry years in the mid-1950s.

The overall goal is to meet user demands and fulfill the actual and implied contract that the SWP will not fail to deliver at least a predetermined minimum supply. Such risk-averse planning and operation creates a situation in which actual supply exceeds firm yield most of the time. SWP managers deal with this by declaring the excess for delivery as surplus rather than contract water. Contract amounts are tied to estimates of minimum project yield, while surplus water is not guaranteed from year to year, and thus acts as a flexible buffer to contracted supplies. This situation is good for users, who can place great confidence in basic SWP supply reliability, as well as benefitting from the sale of cheaper, "surplus" water.

SWP development is guided by a long-term plan which projects a total demand of 3.6 million acre-feet (maf) by the year 2010 (see California Department of Water Resources, 1983). Users set the demand projections by providing DWR with their capital investment plans. Phased facilities development was planned to keep firm yield larger than projected demand, but projects (such as the proposed Auburn Dam and Delta

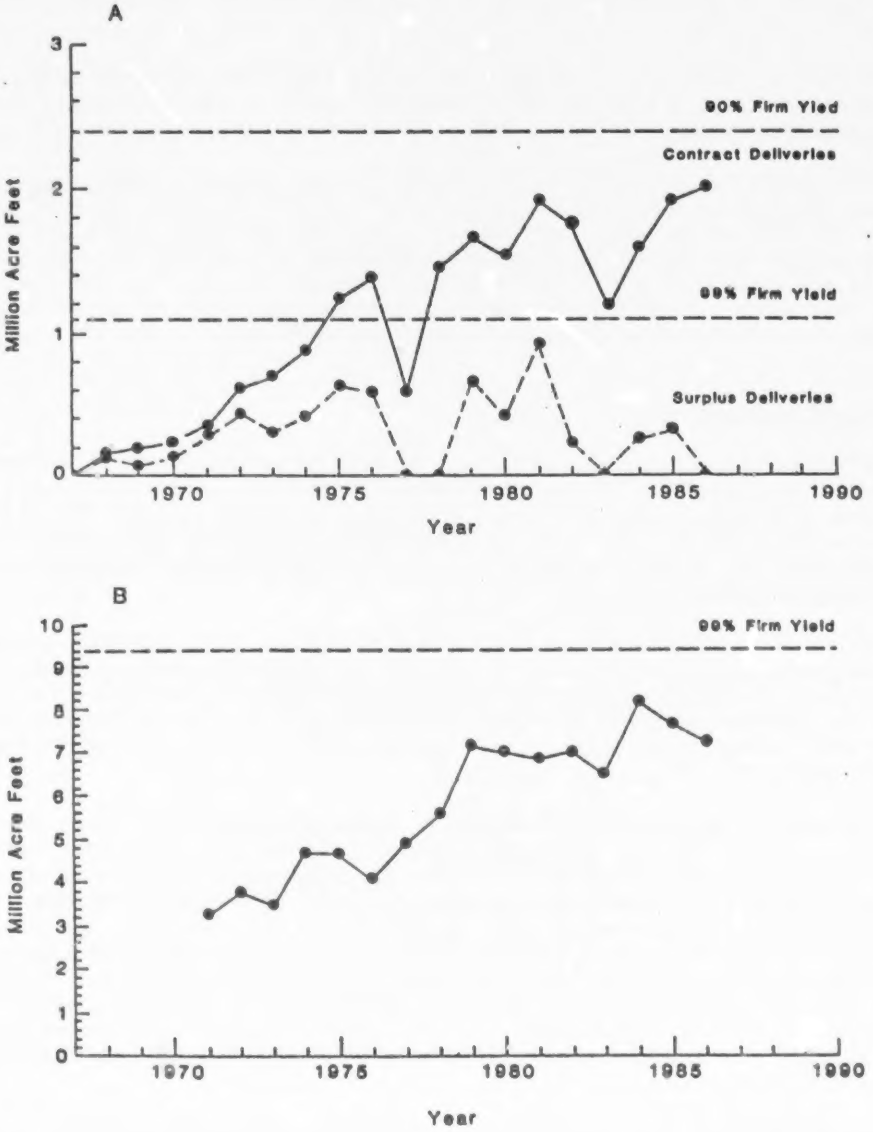

Figure 2. Water deliveries and firm yield levels for (a) the State Water Project and (b) the Central Valley Project.

Peripheral Canal) have been delayed owing to environmental and economic constraints. In concert with the larger-than-expected water requirements for meeting Delta water quality standards (discussed below), these delays have made the SWP quite sensitive to climate impacts in the last decade. This fact as noted in the Coordinated Operations Agreement (U.S. Bureau of Reclamation, 1986) in which CVP and SWP supplies are shared:

> The CVP, for an interim period of time, has water for which it has no facilities to fully deliver that water to federal contractors. The SWP, on the other hand, has conveyance capacity available but an insufficient water supply with which to fully utilize its system (U.S. Bureau of Reclamation, 1986).

That is, the CVP has a surplus of water and the SWP is short, especially in relation to users' projected requirements. These different sensitivities are seen in the two water systems' relative capacities. The CVP has a reliable or firm yield (the amount of water available in all but the driest years, usually calculated to allow shortages damaging to users only once in 100 years of roughly 9.4 maf, while the SWP has a equivalent firm yield of roughly 0.9 maf, and a 90% firm yield (i.e., the amount that can be delivered in 9 out of 10 years) of 2.4 maf (Figure 2). The CVP has delivered between 7 and 8 maf to users over the last several years, while the SWP has been making contracted deliveries of up to 2 maf in recent years and delivering an additional 1 maf in "surplus" water.

Growing Climate Sensitivity Raises User Concerns

SWP planners faced growing constraints on adding new facilities during the 1970s (see Sudman, 1983, and Franceschi and Sudman, 1983). Storage capacity increased little while contract water requests quadrupled (from 0.3 maf to 1.3 maf) between 1970 and 1975, exceeding the project's 0.9 maf 99% firm yield, and approached the 2.4 maf 90% firm yield in the early-1980s (Figure 2). The system was becoming more sensitive to climate fluctuations, and users could reasonably ask whether it would protect them form future drought if new facilities were further delayed.

The 1976-77 drought created a crisis that highlighted its growing climate sensitivity and illustrated the nature of managerial response to climate impacts. The drought produced the driest rainy season on record, causing deliveries to fall below firm yield targets in 1977. Managers curtailed deliveries to avoid eventual storage depletion: firm agricultural water deliveries in 1977 were shorted by 60%, and municipal/industrial supplies were reduced by 10% (California Department of Water Resources, 1978). Total deliveries declined from 2.05 maf in 1976 to 0.9 maf in 1977.

These shortages provoked calls by users and policymakers for an evaluation of dry-year delivery policies --the key management criteria in any water system. Recognizing that they might not be able to increase project supplies in the near future, SWP managers were being forced to make a strategic choice between operating the system to protect its long-term supply or to keep operations flexible. By keeping as much water in storage as possible, a strategy that calls for occasional delivery curtailments early in developing droughts, managers could increase the probability of making future deliveries even under dry conditions. Alternatively, they could accept greater risks of storage depletion by maintaining full contract deliveries as future droughts develop, rather than saving water in storage. The choice, made in the midst of the severe 1976-77 drought, was to protect long-term supply by giving priority to end-of-year storage. This choice meant risking shortages in current-year deliveries that later may have proven to be unnecessary because an incipient drought failed to intensify (California Department of Water Resources, 1977).

This water allocation policy was codified in a "rule curve," which determined deliveries and carry-over storage during periods of short supply (see California Department of Water Resources, 1977 and 1978). Users, who had become skeptical of informal, intuitive water allocation decisions used in the past, supported the more rigid approach at first. Because many users were still making long-term capital investments in the use of contracted water, they approved of the strategy aimed at maintaining the project's ability to deliver even reduced water amounts over the long-term, rather than maintaining full deliveries at the risk of eventual supply depletion (Snow, 1976; Robie, 1976).

The new rule curve was not involved again for several years. Yet, due to continued demand growth, tightened water quality standards in the Delta, and a referendum blocking construction of the Peripheral Canal (which would have increased firm yield by perhaps 1 maf), SWP managers estimated in 1983 that, even with conservative supply management, contract requests would only be satisfied in normal or above-normal runoff years by 1986, and met in only very wet years by 1990, when requests were expected to reach 2.9 maf (California Department of Water Resources, 1983). Given this squeeze on supply, managers and users again called for additional storage facilities to augment dry year supplies (as well as provide more flood control capacity that might allow a relaxation of flood control rules in other reservoirs--see below). They were guardedly optimistic that a major new reservoir could be operating by the year 2000 (California Department of Water Resources, 1983).

Readjusting Allocation Policies

Conservative supply management and growing demand set the stage for the sharp drought of 1985, when the "rule curve" called for significantly curtailed current year deliveries in order to meed minimum needs if the drought continued in the next year. Users reasoned that unnecessary delivery shortages--a frequent problem with rigid allocation criteria in a variable climate--might be worse than simply running out of water further into a multi-year drought.

This attitude change is evident in SWP documents. Noting that the 1977 rule curve "...emphasized credibility at the expense of usability--probably due to the unprecedented drought conditions prevailing at the time it was designed" (California Department of Water Resources, 1985a), SWP managers began to question its usefulness given the growing inadequacy of average supply. The situation had, perhaps, been anticipated 2 years earlier in the 1983 update of the state's water plan:

> ...uncertainty regarding the capability of increasing developed supplies over the next several decades may justify and in fact may require taking greater risks in delivering water to customers....Some water projects (could) take greater risks by delivering a higher annual supply, leaving less carryover storage in case of drought. This would allow growing needs to be met in normal years....(E)xisting facilities may be operating in a more conservative manner than is necessary (California Department of Water Resources, 1983).

This analysis, reflecting poor prospects for increasing raw supply and recent large short-term swings in runoff, set the stage for re-evaluating the dry-year operating procedures. It suggested the following:

> The objective reliability of the Rule Curve procedure (99%) may be more restrictive than intended in Water Supply Contracts, so that the (seasonal) forecast magnitude of available supply has been more limited and (SWP) approval of delivery schedules further delayed during the runoff season than may be warranted (California Department of Water Resources, 1985a).

A new policy emerged: adjust the rule curve each year given current conditions and attempt to maintain full contact deliveries early in a drought by drawing more liberally on reservoir storage (thus accepting greater risk of failing to meet subsequent year demands). This "variable risk" approach would help managers avoid imposing unnecessary shortages during short dry spells, and would make seasonal supply projections less likely to be revised downward.

In the case of the SWP, we observe a complex, crisis-driven policy process that shifted from rigid allocation criteria to more flexible rules as the project became more sensitive to climate impacts. Flexible operations, in lieu of further physical facilities and/or increased raw supply, can help a water system adjust to some climate change. But, the problem is to assess the "absorptive capacity" provided by variable-risk allocation rules.

Summary: Potential Future Adjustments in Water Supply

Options for adjusting California water supplies to climate change (see Table 2) range from continuing the traditional approach of building more and larger physical facilities (at least until all available supply is controlled) to what might be called "softer" options, including a mixture of behavioral (e.g., conservation), institutional (e.g., water marketing) and technical options (e.g., water-reuse, groundwater banking, and smaller, specialized physical facilities like the Auburn "dry dam" for flood control). There is, of course, the possibility that a rapid deterioration of climate, imposed on an already sensitive system, could lead to drastic measures which, in the past, have been needed only in extreme years.

Table 2. Options for Water Supply and Flood Control Adjustments in California

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1) **The traditional option**: build larger facilities/increase supplies: Given sufficient public will and financing, new and larger reservoirs and water conveyance facilities could be built to reduce the impacts of climate change. Ultimately, however, the last drop of water available in the state or already allocated for importation from the Colorado River, would be utilized, or new facilities would e blocked by economic and environmental constraints, and new options--like waste water reclamation, cloud seeding, desalinization, or imports from beyond the Colorado Basin--would be required. Many of these options have been mentioned in recent water plan updates. There has been a large interest in weather modification in the past and this adjustment would most likely re-emerge in any future supply shortage.

2) **A broad range of incremental adjustment**: The most likely response to climatic and other threats to reliable, quality water supply, is a mixture of incremental behavioral and institutional changes, including conservation, water re-use, enhanced joint-system management, and reallocation of supplies via some form of water marketing. the 1987 update of the state's water plan promotes a form of broad-range adjustment, yet it still evinces a bias toward new, but smaller, physical facilities and structural improvements.

3) **The draconian alternative**: If climate conditions were to worsen dramatically in the next few years in the area, and given the growing climate-sensitivity already exhibited by present water systems, decision-makers might be pressed to instigate dramatic water-use restrictions, essentially implementing permanently, the "emergency" measures taken during recent droughts. Among these adjustments would be prohibiting most "non-essential" uses, and quicker transfers of agricultural water to municipal and industrial uses.

A "wild-card" in this list of broad alternative responses is the real and perceived need for flood control--which conflicts with supply management. If there is pressure to increase flood protection by decreasing reservoir storage in the basin, say if spring runoff increases due to the greenhouse effect, then the ability to meet demand will decrease. The trade-off between water supply and flood control in northern California represents a potentially serious policy conflict affecting all levels of government in the region. While some climatic shifts (e.g., a smoothing of the area's marked precipitation seasonality) would ease this tension, even small shifts toward earlier runoff or more extreme rainfall events would worsen the supply/flood control trade-off situation. Given that similar tensions exist in other water systems that provide both flood control and water supply (e.g., the Colorado River), there is a need for a broad assessment of this issue vis-a-vis changing water demands and potential climate change.

The overarching trend in water resource development policy in northern California over the last decade has been a de-emphasizing of large physical facilities. Project planners recognize a need to re-establish a buffer between supply and demand, but have been constrained by institutional forces (e.g., water law and existing water user charters) not to turn to economic or other strategies (i.e., through competitive bidding or water right sales--water marketing--which might yield more efficient allocation) to achieve a supply less sensitive to climatic inputs.

Thus, their plans continue to include new physical facilities despite growing financial and environmental constraints on this traditional approach to water system development.

Without having explicitly considered potential climate change as a rationale, the recently revised development plan for the SWP (California Department of Water Resources, 1987) includes several actions and facilities that would allow the system to absorb at least small climate changes. Spurred by success of coordinated operations with the CVP (aimed mostly at meeting Delta water quality requirements and dry-year demand), the state and federal governments are discussing further sharing (probably additional water purchases from the CVP) and further "optimizing" of joint project management. Indeed, the 1987 plan actually suggested the possibility of state management of both SWP and CVP facilities. Completely joint management could produce more than 1 maf additional firm yield in the system.

Besides operational adjustments, the 1987 plan calls for construction of offstream storage at Los Banos Grandes south of the Delta (an approach and site less likely to draw serious environmental opposition than, say, Auburn Dam), and improvements in Delta pumping and conveyance facilities. Through these strategies, the SWP plans to achieve a 90% firm yield of roughly 3.3 maf by 2010 (Figure 3), just short of expected demand (which tends to be overestimated) of 3.6 maf. Thus, supply and demand will still be closely balanced, but there will be more of a safety margin than presently exists. This will allow for more flood control space in reservoirs, as well as minimizing the threat of supply depletion during the driest years. Thus, the project adjustments suggested in the 1987 plan would help the SWP absorb at least some of the greenhouse climate change possible over the next few decades.

DELTA ISLANDS LAND USE AND MAINTENANCE ISSUES

Maintenance of the system of levees and islands in the Sacramento-San Joaquin Delta is another climate-sensitive policy issue in Northern California. The Delta faces two key threats from climate change: reduced runoff and sea level rise. It is becoming more climate-sensitive, even in the absence of climate change, due to natural and anthropogenic land degradation.

Located near the confluence of the Sacramento and San Joaquin Rivers, this freshwater delta lies at the heart of California's water supply system (Figure 4). The Delta is "probably...the State's most valuable water supply" element (California Department of Water Resources, 1987). A system of levees assists in maintaining the freshwater character of the Delta by repelling the eastward intrusion of salt water from San Francisco Bay. The repulsion of salt water is necessary to maintain quality at CVP and SWP pumping stations in the southern Delta. Fresh water in the Delta is also important to wildlife and recreation. In addition, the levee system protects land use on the islands in the Delta, most of which are below sea level (Figure 5). These islands are used mainly for agriculture, but also contain small communities and their associated infrastructures. In light of these varied uses and benefits, federal, state, and local agencies have an interest in preserving the system of levees and islands.

Less than 150 years ago, the 700,000 acres of the Delta were sea level freshwater and tidal marsh. Through marsh reclamation and damming and diverting of the Sacramento and San Joaquin Rivers, the Delta has gradually been transformed from a natural, fluctuating environmental system into an artificially maintained one. Today the Delta contains roughly 60 islands protected by 1100 miles of levees. These islands and levees are constructed mostly of the Delta's indigenous peat, sand, and silt soils. Wind erosion, oxidation, compaction, and consolidation of these soils have reduced the land surface of almost all of the islands to below sea level (Figure 5). Levee failures are common occurrences: Since original reclamation, each of the 70 islands and tracts in the statutory Delta (defined in Section 12220 of the California Water code) has been flooded at least once. Over 100 levee failures have occurred since the early 1890s.

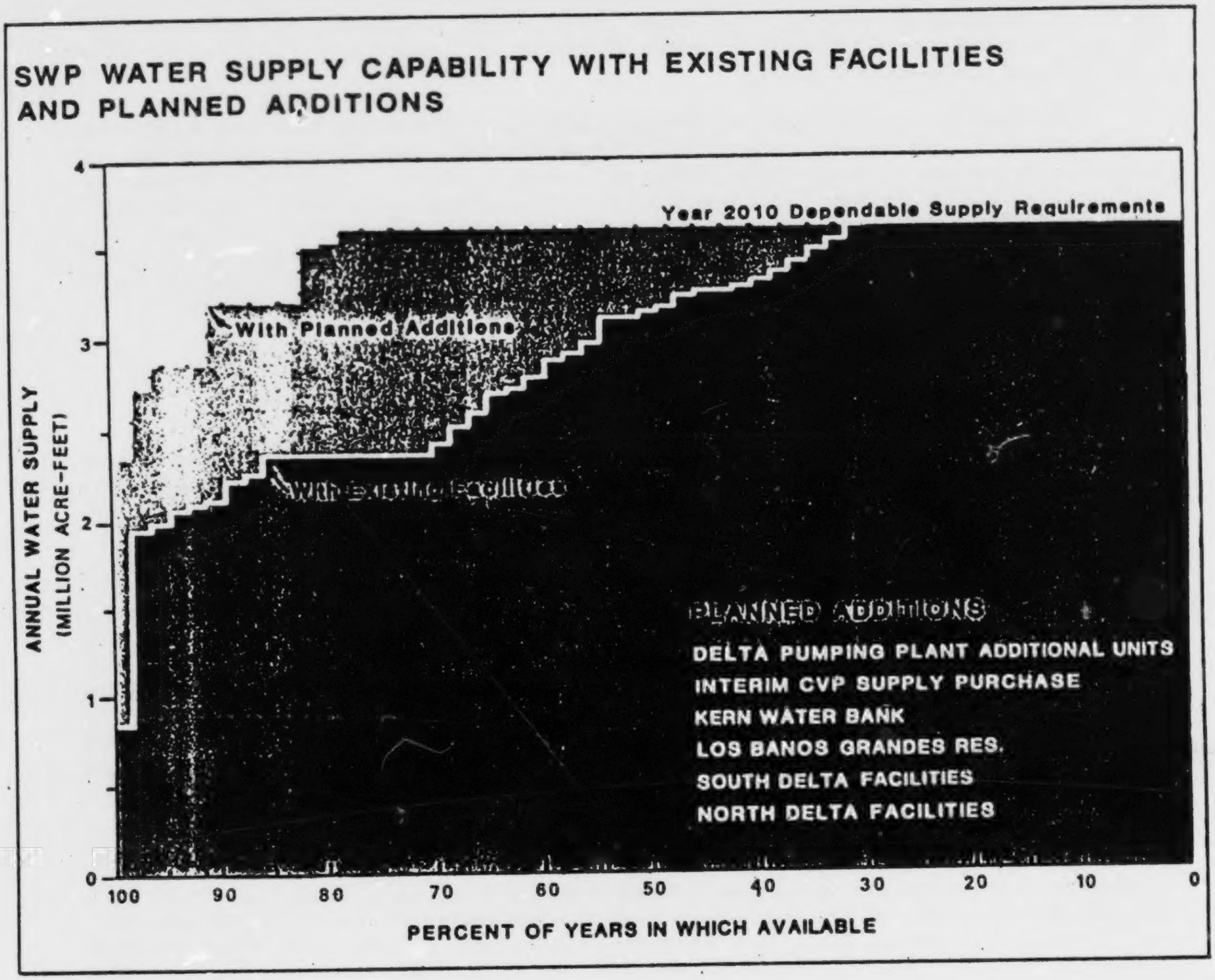

Figure 3. State water project projections of demand and supply.

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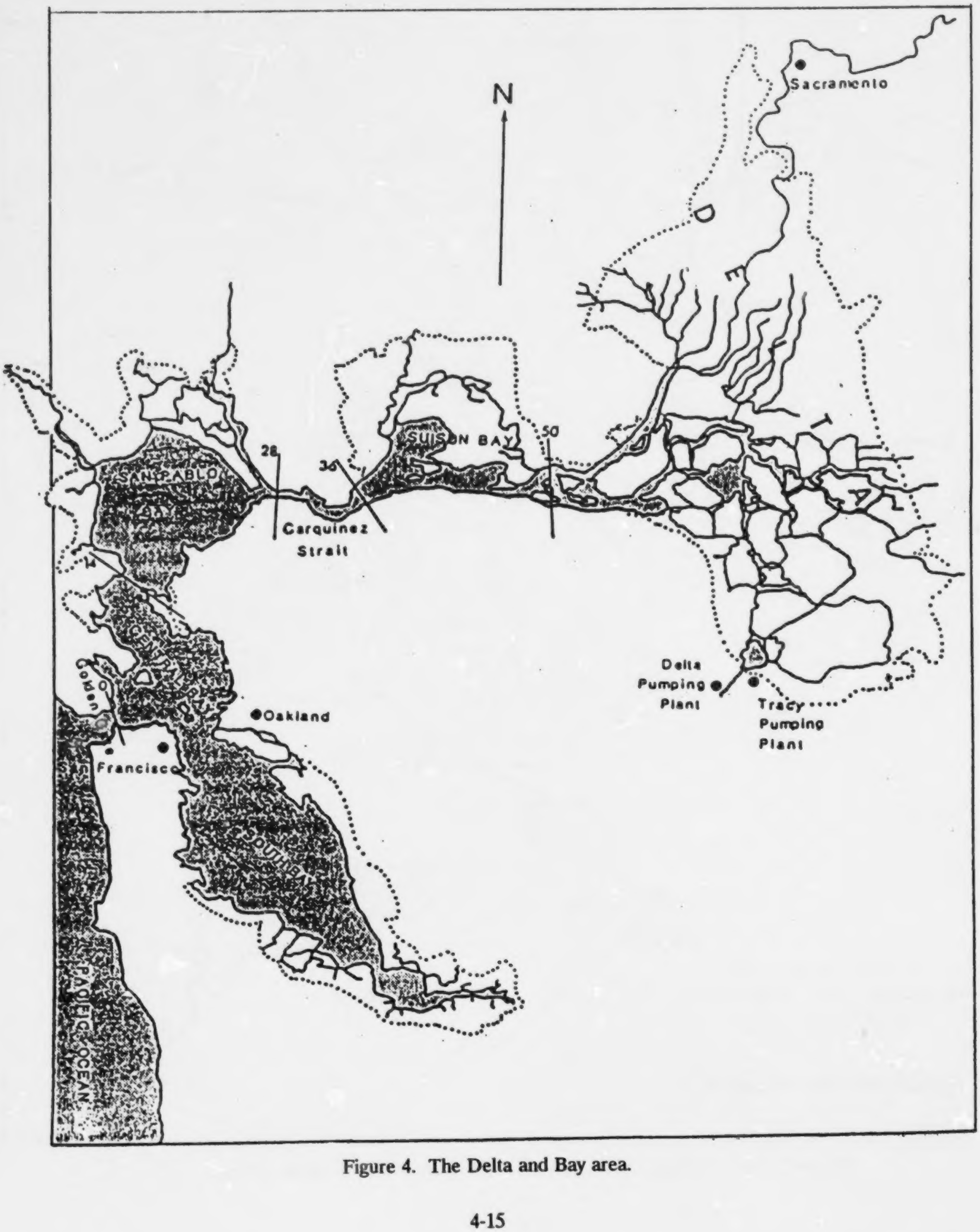
N
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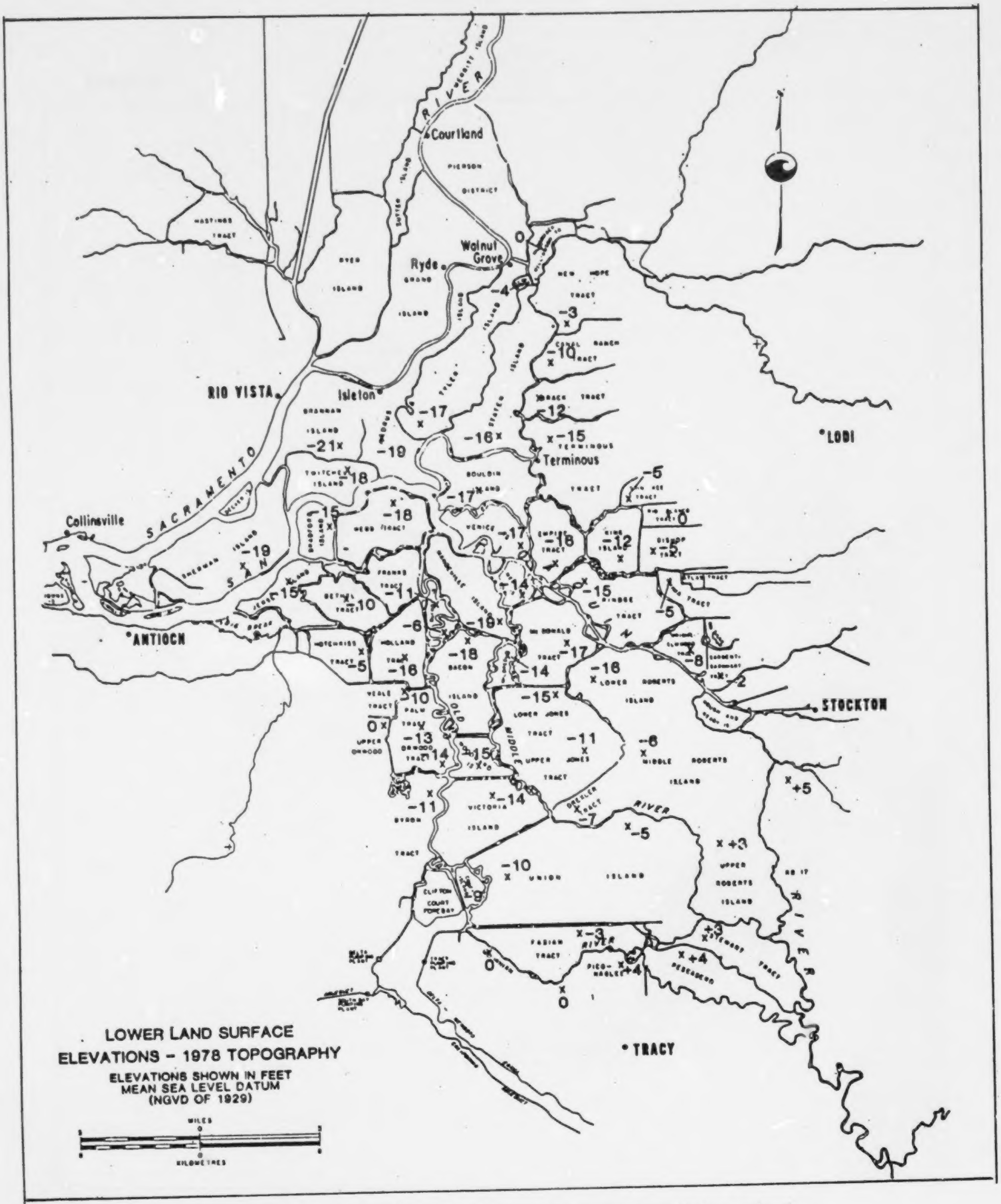
Carquinez Strait
14
CENTRAL BAY
Golden Gate
Oakland
San Francisco
SOUTH BAY
PACIFIC OCEAN
Delta Pumping Plant
Tracy Pumping Plant

Figure 4. The Delta and Bay area.


LOWER LAND SURFACE ELEVATIONS - 1978 TOPOGRAPHY
ELEVATIONS SHOWN IN FEET MEAN SEA LEVEL DATUM (NGVD OF 1929)
MILES
KILOMETRES
SACRAMENTO RIVER
SAN JOAQUIN RIVER
Courtland
PIERSON DISTRICT
HASTINGS TRACT
RYER ISLAND
GRAND ISLAND
Ryde
Walnut Grove
RIO VISTA
Isleton
LODI
Terminous
Collinsville
ANTIOCH
STOCKTON
TRACY
BRANNAN ISLAND
TWITCHELL ISLAND
SHERMAN ISLAND
WEBB TRACT
BETHEL TRACT
HOLLAND TRACT
BACON ISLAND
VICTORIA ISLAND
UNION ISLAND
BYRON TRACT
FABIAN TRACT
LOWER JONES TRACT
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MIDDLE ROBERTS ISLAND
UPPER ROBERTS ISLAND
NEW HOPE TRACT
TERMINOUS TRACT
BOULDIN ISLAND
VENICE ISLAND
EMPIRE TRACT
KING ISLAND
RINDGE TRACT
McDONALD TRACT
PALM TRACT
ORWOOD TRACT
UPPER ORWOOD
VEALE TRACT
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STEWART TRACT
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-7
-5
+5
+3
-10
-9
-3
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+3
+4
+4
0

Figure 5. Delta land elevations showing lands below sea level (minus values).

The Delta Problem

Simply stated, the Delta islands are threatened with catastrophic degradation due to sea level rise, land subsidence, wave and current action, and levee deterioration. Also, any changes in freshwater inflow to the Delta or outflow to San Francisco Bay, due to climate change or to consumptive changes, affect Delta water quality. Thus, in addition to being a valuable component in the state's water supply system, the Delta may also be viewed as the "weak link" in that system. The Delta problem is particularly complex because of the many public and private interests with a stake in the issue. The key question raised in any consideration of the climate threat is, simply, how much effort, and with what policy mechanisms, is to be committed to maintaining the Delta in the face of physical threats.

We approach this question by first describing the policies and institutions that affect the Delta. Once this "policy landscape" is laid out, it is possible to discern likely response to near-future climate change.

Institutions and Policies Affecting Delta Maintenance

The Delta and levee problem comes under the purview of several public institutions, each with different responsibilities and concern. Indeed, this issue may eventually prove more controversial than water supply and flood control. Thus, in analyzing the policy implications of climate threats to the Delta, a somewhat different approach is taken than in the water supply area. The approach here is to examine in detail the institutions and policy tools that will come into play if climate change and sea level rise further threaten the Delta. Throughout this section we focus on those policy trends and mechanisms which point to a continuing effort to protect the Delta at any cost.

The U.S. Army Corps of Engineers (USACE) and Regulatory Policies. The USACE plays a regulatory (rather than its typical construction and operation) role in Delta levee maintenance. Although the USACE has build some Delta levees, the maintenance and upkeep of the privately owned, "non-project levees" (Figures 6 and 7), which comprise 95% of the Delta levee system, is the responsibility of the individual owners. However, if levee owners (or local reclamation district, which serve as representatives of individual levee owners) wish to make repairs or improvements on a levee, they are required to obtain a permit from the USACE.

But the USACE has a blanket mechanism for permitting levee construction and maintenance, called a "nationwide permit," that authorizes broad categories of activities like dredge and fill for water resources management throughout the country. In the Delta case, a commonly used nationwide permit is a "No. 3," which allows for "repair, rehabilitation, or replacement of a structure or fill which was previously authorized and currently serviceable." If this repair does not deviate from the structure's original plans, no additional permit must be obtained to carry out the work.

In cases of major work on a levee that changes its original design, the owner may have to obtain a "Section 10" permit. Section 10 of the Rivers and Harbors Act of 1889 requires approval prior to any work in or over navigable waters, or which affects the course, location, condition, or capacity of such waters (all tidal waters are considered navigable; all Delta waters are tidal and, hence, navigable). Typical activities requiring Section 10 permits are the construction of piers, wharves, marina ramps, dredging, and excavation.

Construction or maintenance activities that result in some material being deposited onto wetlands, or into existing water bodies, require a "Section 404" permit (pursuant to Section 404 of the Clean Water Act). Typical 404 permit activities include deposition of dredged or fill material, as well as construction of levees, dams, and dikes.

These permitting processes are used today mostly for environmental protection, and they might, in theory, result in delayed or reduced maintenance, or even in the consideration of alternatives to continued maintenance. However the USACE can also issued a permit for "Emergency Bank Rehabilitation" (General Permit No. 35--GP-35). This permit is issued under the authority of Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act, and is available only in the Sacramento and San Joaquin drainage

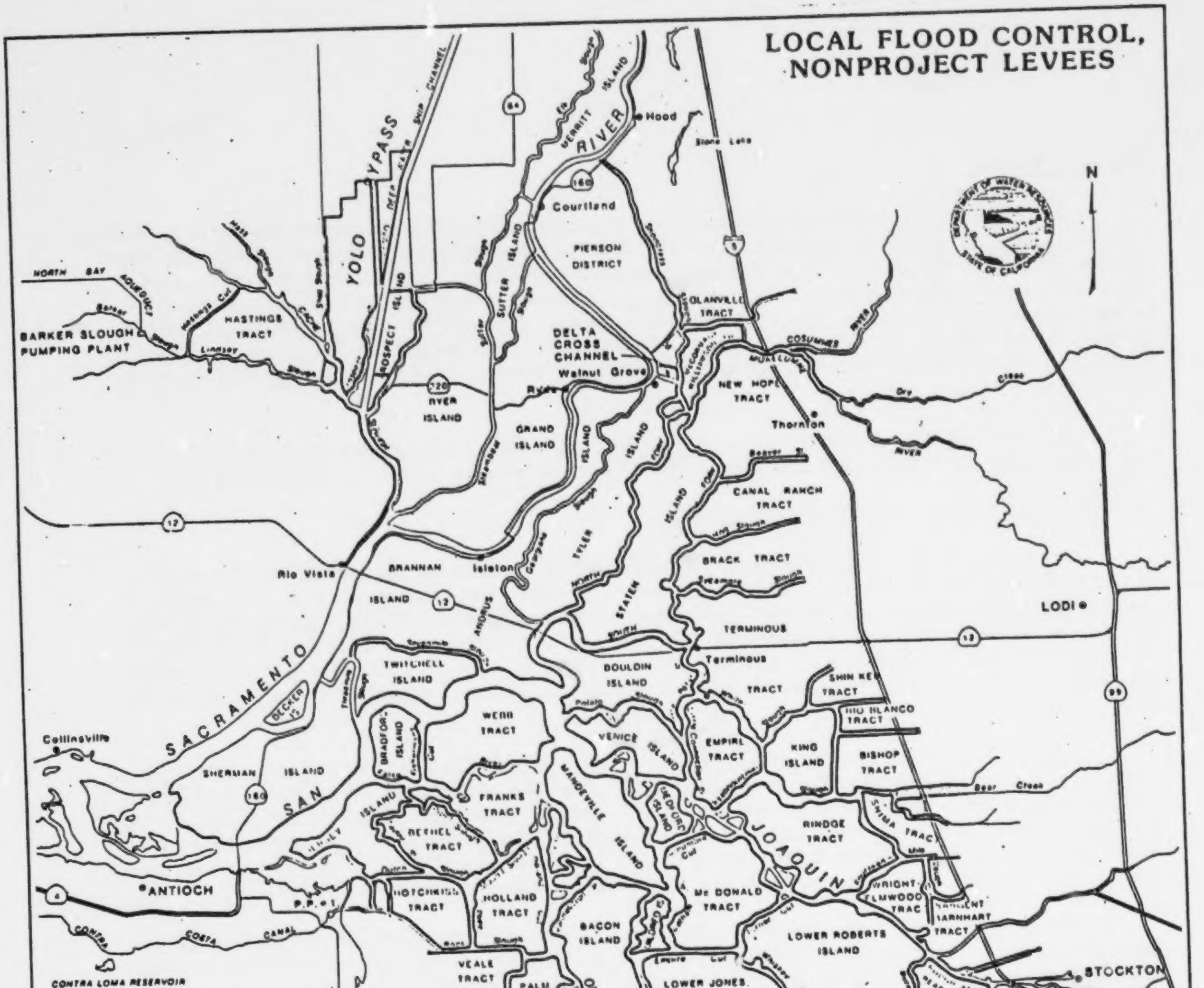

LOCAL FLOOD CONTROL,
NONPROJECT LEVEES
N
YOLO BYPASS
RIVER
Hood
Courtland
PIERSON DISTRICT
SUTTER ISLAND
PROSPECT ISLAND
GLANVILLE TRACT
HASTINGS TRACT
NORTH BAY AQUEDUCT
BARKER SLOUGH PUMPING PLANT
DELTA CROSS CHANNEL
Walnut Grove
Ryde
COSUMNES RIVER
NEW HOPE TRACT
Thornton
RYER ISLAND
GRAND ISLAND
CANAL RANCH TRACT
BRACK TRACT
TERMINOUS
Terminous
Rio Vista
BRANNAN ISLAND
Isleton
ANDRUS
TYLER ISLAND
STATEN ISLAND
LODI
SACRAMENTO
TWITCHELL ISLAND
DECKER IS.
BOULDIN ISLAND
SHIN KEE TRACT
RIO BLANCO TRACT
WEBB TRACT
VENICE ISLAND
EMPIRE TRACT
KING ISLAND
BISHOP TRACT
Collinsville
SHERMAN ISLAND
BRADFORD ISLAND
SAN
FRANKS TRACT
MANDEVILLE ISLAND
RINDGE TRACT
BETHEL TRACT
JOAQUIN
ANTIOCH
HOTCHKISS TRACT
HOLLAND TRACT
McDONALD TRACT
WRIGHT-ELMWOOD TRACT
TERMINOUS
CONTRA COSTA CANAL
BACON ISLAND
LOWER ROBERTS ISLAND
CONTRA LOMA RESERVOIR
VEALE TRACT
PALM TRACT
OLD
LOWER JONES TRACT
STOCKTON
Brentwood
ORWOOD TRACT
WOODWARD IS.
UPPER JONES TRACT
DISCOVERY BAY
MIDDLE
MIDDLE ROBERTS ISLAND
VICTORIA ISLAND
RIVER
BYRON TRACT
Byron
UNION ISLAND
UPPER ROBERTS ISLAND
CLIFTON COURT FOREBAY
Grant Line Canal
Fabian and Bell Canal
FABIAN TRACT
STEWART TRACT
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
SOUTH BAY PUMPING PLANT
TRACY
DELTA-MENDOTA CANAL
CALIFORNIA AQUEDUCT
SACRAMENTO - SAN JOAQUIN DELTA
2 0 2 4 6
SCALE IN MILES

Figure 6. Non-federal levees in the Delta.

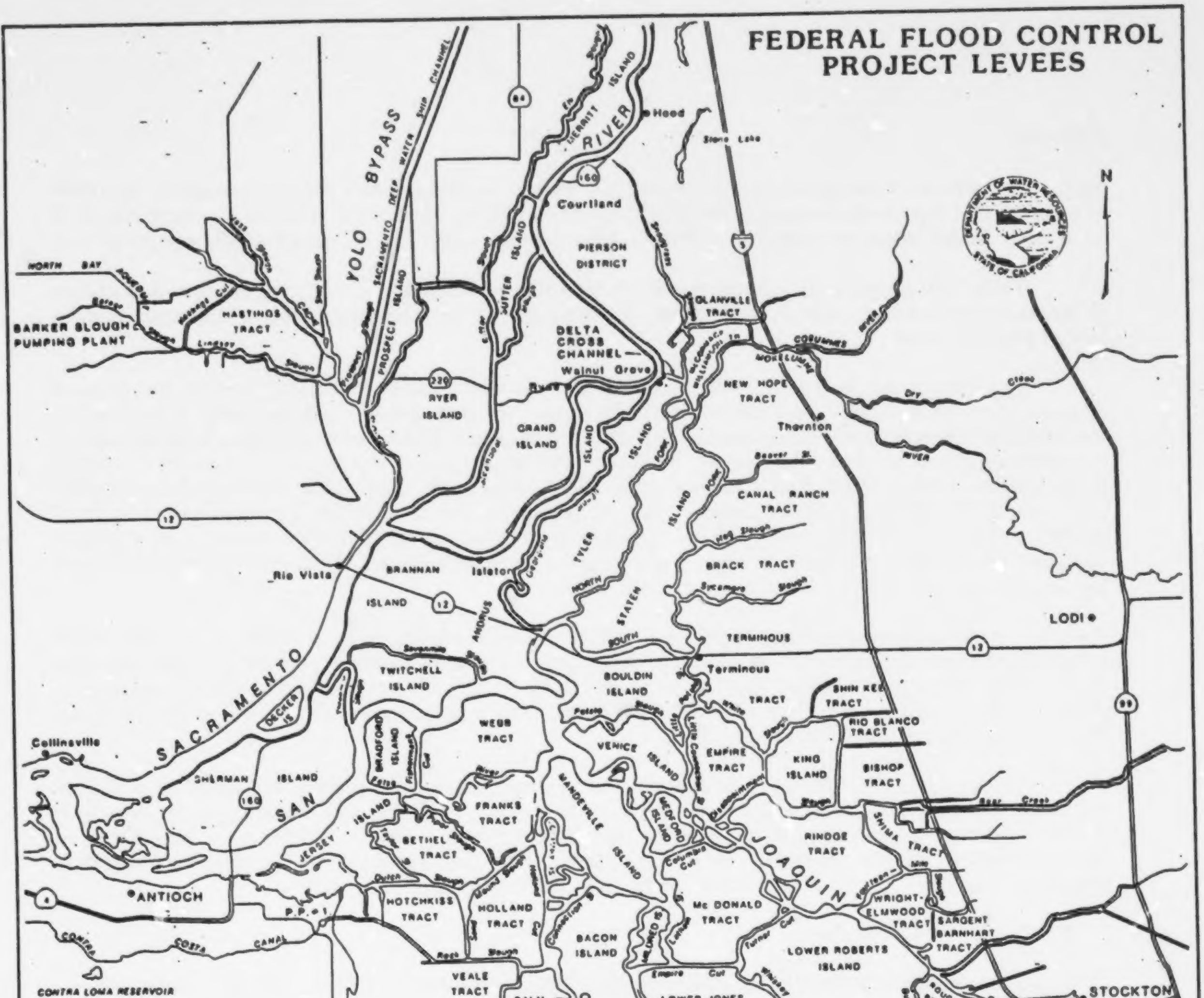

FEDERAL FLOOD CONTROL PROJECT LEVEES
N
STATE OF CALIFORNIA
YOLO BYPASS
SACRAMENTO DEEP WATER SHIP CHANNEL
PROSPECT ISLAND
RIVER
MERRITT ISLAND
Hood
Stone Lake
Courtland
PIERSON DISTRICT
SUTTER ISLAND
NORTH BAY AQUEDUCT
BARKER SLOUGH PUMPING PLANT
HASTINGS TRACT
Lindsey Slough
Cache Slough
GLANVILLE TRACT
DELTA CROSS CHANNEL
Walnut Grove
Ryde
RYER ISLAND
GRAND ISLAND
COSUMNES RIVER
MOKELUMNE
NEW HOPE TRACT
Thornton
Dry Creek
RIVER
Beaver Sl.
CANAL RANCH TRACT
Hog Slough
BRACK TRACT
Sycamore Slough
TYLER ISLAND
STATEN ISLAND
NORTH FORK
SOUTH FORK
Rio Vista
BRANNAN ISLAND
Isleton
ANDRUS
LODI
TERMINOUS
Terminous
TERMINOUS TRACT
SHIN KEE TRACT
RIO BLANCO TRACT
BISHOP TRACT
KING ISLAND
EMPIRE TRACT
White Slough
Bear Creek
SACRAMENTO
DECKER IS.
TWITCHELL ISLAND
Sevenmile Slough
BOULDIN ISLAND
Potato Slough
WEBB TRACT
VENICE ISLAND
BRADFORD ISLAND
Collinsville
SHERMAN ISLAND
SAN
JOAQUIN
JERSEY ISLAND
BETHEL TRACT
FRANKS TRACT
MANDEVILLE ISLAND
MEDFORD ISLAND
Columbia Cut
RINDGE TRACT
SHIMA TRACT
WRIGHT-ELMWOOD TRACT
SARGENT BARNHART TRACT
ANTIOCH
P.P. #1
CONTRA COSTA CANAL
CONTRA LOMA RESERVOIR
HOTCHKISS TRACT
HOLLAND TRACT
Rock Slough
Dutch Slough
BACON ISLAND
MILDRED IS.
Mc DONALD TRACT
Turner Cut
LOWER ROBERTS ISLAND
Empire Cut
STOCKTON
ROUGH AND READY IS.
VEALE TRACT
PALM TRACT
OLD
LOWER JONES TRACT
Whiskey Slough
Brentwood
ORWOOD TRACT
WOODWARD IS.
UPPER JONES TRACT
DISCOVERY BAY
MIDDLE
MIDDLE ROBERTS ISLAND
VICTORIA ISLAND
BYRON TRACT
Byron
RIVER
Victoria Canal
North Canal
UNION ISLAND
UPPER ROBERTS ISLAND
CLIFTON COURT FOREBAY
CONEY ISLAND
Grant Line Canal
Fabian and Bell Canal
FABIAN TRACT
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
OLD RIVER
Paradise Cut
STEWART TRACT
Tom Paine Slough
AQUEDUCT
SOUTH BAY PUMPING PLANT
SOUTH BAY
DELTA-MENDOTA CANAL
CALIFORNIA AQUEDUCT
TRACY
SACRAMENTO - SAN JOAQUIN DELTA
2 0 2 4 6
SCALE IN MILES
84
160
220
12
4
5
99
120
205

Figure 7. Federal levees in the Delta.

basins. The purpose of this permit is to allow emergency repair of eroded levees and streambanks by the DWR or its authorized representative (usually the local reclamation district). The intent of GP-35 is to authorize work on severely eroded levees when there is a threat to levee integrity which poses a hazard to life or property loss.

Thus, federal regulatory mechanisms for maintaining the status quo, and fighting physical degradation of the Delta due to climate change, are in place. A similar set of state policies also support maintenance in the face of physical threat.

The Reclamation Board. The Reclamation Board was established in 1911 to help oversee flood control efforts in the Central Valley. The Board also has jurisdiction over all project levees in the Delta. It thus assures the federal government that Delta levees will be properly maintained. The actual maintenance is usually carried out either by a local reclamation district of the DWR. The law governing The Reclamation Board is codified in the California Water Code, Part 4, Sections 8520-9377. Other parts of the Code, especially Sections 8340-9577 and 12878-12878.45, inclusive, assign responsibilities to the Board regarding the maintenance of flood protection works. Since 1956, the Board has been administratively part of the DWR. However, by statute, it continues to function as a separate agency in exercising its responsibilities for flood management on the Sacramento and San Joaquin Rivers and their tributaries.

Another important function of the Board is the co-administration, with the DWR, of the State Delta Levee Maintenance Subventions Program. In 1973, the State Legislature passed Senate Bill 541--also known as the Way Bill--which provides State financial assistance to Delta agencies for maintaining and improving non-project Delta levees for flood protection of Delta islands. This program operates pursuant to the California Water Code, Chapter 3, Sections 12980-12991.

Section 12981 of the Water Code states, "...the physical characteristics of the Delta should be preserved essentially in their present form, and that the key to preserving the delta's physical characteristics is the system of levees defining the waterways and producing the adjacent islands." However, this stance has since been "softened" with the addition of another sentence to section 12981 in 1985 which states: "However, the Legislature recognizes that it may not be economically justifiable to maintain all Delta islands."

Section 12982 also states:

> The Legislature further finds and declares that while most of the Delta's levees are privately owned and maintained they are being subjected to various multiple uses and serve to benefit many varied segments and interests of the public at large, and that as a result of the varied multiple uses of such levees, added maintenance costs are being borne by adjacent landowners.

Thus, there exists a formal policy statement in support of maintaining the levees against physical threat. Of course, there is a range in values of the Delta islands. Some islands contain communities and highways, for instance, while others are strictly agricultural. Although the general policy is for maintenance of the present Delta configuration, there is precedence for allowing some inundation to go unreclaimed. In 1983, Mildred Island's 997 acres of strictly agricultural land, which had recently sold for roughly $1 million, were flooded by levee failure. Estimated total costs of its reclamation, including public and private funds, have ranged from $5 to $10 million, and, consequently, it has not been reclaimed. (Section 12981 was one reason cited for not reclaiming the island.) But other islands are certainly more likely to be protected and to be reclaimed if flooded. In addition to increasing real estate values, islands in the western Delta are important in repelling salt water intrusion. Failure of one of these islands would undermine water quality in the Delta and would reverberate upstream to water supply and flood control activities.

Currently, the State of California funds the Delta Levee Subvention Program at $2 million annually. Pursuant to Section 12986, these monies are distributed to the local reclamation districts in the following manner:

1) No costs incurred shall be reimbursed if the entire cost incurred per mile of levee is $1000 or less.

2) Fifty percent of any costs incurred in excess of $1000 per mile of levee shall be reimbursed.

Efforts are under way to increase funding of the Subventions Program. A bill proposed by state Senator Boatwright (Senate Bill No. 34), would, until January 1, 1999, "...authorize reimbursement for 75% of any costs incurred in excess of $1,000 per mile of levee and delete the $2,000,000 per year limitation." In addition, "...The bill would, until January 1, 1999, create the Delta Flood Protection Fund, would declare legislative intent to appropriate $12,000,000 each year to the fund through fiscal year 1998-1999 from specified tidelands oil and gas revenues and would declare legislative intent to annually appropriate from the fund $6,000,000 for local assistance for the maintenance and improvement of delta levees...and $6,000,000 for special delta flood protection projects and for subsidence studies and monitoring."

Thus, the Subventions Program funding would be increased to $6,000,000 annually and $6,000,000 would be allocated to flood protection projects and subsidence studies and monitoring. Funds allocated for these projects, studies, and monitoring, "...shall only be allocated for projects on Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb islands in the delta..." These islands are clustered in the western Delta, and here the Legislature may be showing more its concern for overall water quality problems rather than a simple commitment to island maintenance. According to many California water management officials, the passage of this bill is imminent.

Local Reclamation Districts. Local reclamation districts are representatives of the private owners of Delta levees and islands. These districts do most of the maintenance on the levees within the Delta and have the authority to raise funds form three major sources:

1) The California Water Code empowers the districts to create and update assessment rolls of the lands within their boundaries on which the governing board can periodically level assessment.

2) The reclamation districts' governing boards are also mandated by the Water Code to establish a schedule of charges and fees for services and benefits provided by the districts.

3) Those districts that use county assessment rolls to levy special taxes for levee maintenance continue to receive an allocation under the post-Proposition 13 tax collection by the county, which includes property revenues and state subventions.

Until 1980, funds made available for levee maintenance and restoration from these sources had been relatively small--less than $1 million per year. However, due to the large number (24) of levee failures since 1980, the local districts were assessed up to their capacity to pay. Because of this trend of increased levee failures, the Federal Emergency Management Agency (FEMA) and other emergency services agencies have played an increasingly important role in the levee maintenance and repair issue.

Emergency Service Agencies. In the event that a levee failure is part of a flood or storm which becomes a federally declared national disaster, the Federal Emergency Management Agency provides emergency repair funds. These funds are administered pursuant to Public Law 93-288 (PL 93-288)--the Disaster Act. Generally, federal funds are combined with state funds on a 75:25 basis during federally declared emergencies. The funds provided by FEMA flow through the State of California Office of Emergency Services (OES) to local reclamation districts, counties, and cities.

Due to the recent increase in the number of floods in the region (discussed in the water supply section) and resulting levee failures, FEMA felt they were providing too much money for emergency repairs. They pushed to have Delta levees upgraded to minimum standard, as stated in the recent Flood Hazard Mitigation Plan (Office of Emergency Services, 1986). The plan, required in all federal flood disasters, also proposed a levee inspection program to be carried out by the DWR. This inspection is to be made annually and the results reported to FEMA. The DWR does not have the power to make local districts comply with their recommendations for levee standards or with the Inspection Plan. However, if the local districts do not upgrade their levees to or above the standards described in the "Short-Term Rehabilitation Plan" (Park 4, Section c, No. 2, of the Flood Hazard Mitigation Plan), they may lose eligibility for FEMA-sponsored emergency funds in the future.

In 1986, FEMA, the OES, and the local reclamation districts signed an amendment to the Flood Hazard Mitigation Plan stating that in order for local reclamation districts to receive federally sponsored disaster aid, they must commit to upgrading levees to at least the minimum standards set forth in the Mitigation Plan (i.e., 1 foot of levee freeboard above 100-year flood elevations) within a 5-year period. Thus, the Hazard Mitigation Plan provides another policy mechanism for fighting climate impacts.

Summary: Delta Protection Has Large Institution Backing, But Increasing Climate Threat May Eventually Force Alternatives

It is reasonable to expect that the broad array of agencies, policy mechanisms, and interests lined up to protect the Delta islands, even in the face of major threats from sea level rise and other climate change phenomena, will result in substantial public investment if, indeed, the physical threat increases. A range of possible response options is given in Table 3 (see also MacCracken et al., 1987).

Table 3. Range of Options in Delta Land Use

1) **Inaction**: This would probably result in the formation of a large, brackish inland sea as levees fail and salt water penetrates farther inland.

2) **Maintenance of status quo**: This will require strengthening and extending the levee system.

3) **Construction of polder levees**: This entails enclosing groups of islands with levees to form large polders. Such a proposal has generally been deemed unsuitable by recreational and wildlife interests.

4) **"Strategic Inundation"**: This hypothetical strategy (no agency has formally proposed it) allows for the permanent flooding of islands which have no or little role in repelling salt water intrusion and have relatively low land values. Efforts could be made to capitalize on the alternative benefits of the open water and marsh created by this, and to create a circum-Delta conduit for water transfers to the California Aqueduct (something like the Peripheral Canal, now referred to as some form of "isolated canal").

It can be argued that, given the importance of the Delta to California's water supply and quality, and the California Legislature's commitment to "preserving the Delta's physical characteristics," inaction is not a likely option. Indeed, the forces for maintaining the Delta in something close to its current configuration are great, and, thus, maintenance of the status quo is the most likely general policy goal over the next several years.

The idea of mega-levees enclosing groups of islands as "polders" in the Dutch tradition is feasible from an engineering standpoint, but, although it has been mentioned, has received little attention. Similarly, some form of "Delta sacrifice" or strategic retreat in Delta land use might be appropriate given the potential for large protective investments that are eventually overwhelmed, but it is probably unacceptable to most Delta interests.

Recently, however, the Legislature indicated that it might "soften" its stance towards Delta island reclamation (see the 1985 addition to Section 12981 of the California Water code), and it is possible that something approximating a strategic inundation policy might emerge over the next few decades. Sea level rise will increase the frequency of levee failures (Figures 8 and 9). The case of Mildred Island--a relatively low-value island that is not required to maintain Delta water quality--is instructive; it has remained flooded since the 1983 levee failure because estimated reclamation costs outweigh its value. If the threat of levee failure and the cost of maintaining levees increases in the face of climate change over the next several years, it is possible that more land will remain unreclaimed.

DELTA WATER QUALITY ISSUES

Another potential consequence of climate change and sea level rise in the Sacramento-San Joaquin region is the further eastward intrusion of salt water into the Delta. The Bay-Delta system can be crudely divided into three sections based on water quality: 1) the fresh water Delta, 2) the dilute sea water of San Pablo Bay and the more saline San Francisco Bay, and 3) the brackish water of Suisun Bay. An estuarine environment like Suisun Bay, where fresh water mixes with saline oceanic waters, is critical to several aspects of resource management in the region. The planktonic richness of the Bay produces nursery conditions for striped bass and other species (Davoren and Ayres, 1983). But, the system is quite sensitive to climatic inputs. During 1977, when Sacramento-San Joaquin River discharge dropped to a new record low (below 100 m^3sec-1), phytoplankton, zooplankton, and striped bass abundance were all significantly reduced (Nichols et al., 1986). Rising sea level would likely force this null zone eastward into the Delta.

Withdrawals of fresh water from the southern Delta by the SWP and CVP further encourage the eastward-moving salt water flux. When fresh water flow from the Sacramento River is low, SWP pumping plants filling the California Aqueduct for water exports to southern California may cause reverse flows by drawing water from the San Joaquin River. Under such circumstances, water in the western Delta becomes brackish as it mixes with salty ocean water entering the Delta under tidal flow. It was this tidal flow, intensified by persistent onshore winds, that caused water supply allocation problems in the SWP during 1985 (as described above). Further eastward penetration of this brackish water would have obvious, serious consequences for the SWP and CVP and their respective contractors. Increased fresh water outflow from the Delta could help repel this intrusion. However, an increase of fresh water outflow would require the diversion of water from the southern Delta's pumping plants and the agricultural and urban interests they serve.

Institutions and Policies Arrayed for Water Quality Maintenance

As in the maintenance of the Delta levee system, responsibilities and interests in the repulsion of sea water from the Delta overlap among many different agencies and interest groups. This section discusses the commitments and responsibilities of the main players in this climate-sensitive issue.

State Water Resources Control Board (SWRCB). The SWRCB is arguably the pivotal agency involved in the issue of salt water intrusion, as well as Bay-Delta water quality in general. The Board, established by the State Legislature in 1969, is divided into two statutory divisions: water rights and water quality. The powers of the Board are spelled out in the Porter-Cologne Water Quality Control Act. The Board's water right authority is quite distinct and separate from its water quality authority. Its water right function is strictly a state responsibility, while its water quality control authority is pursuant to the Porter-Cologne Act as well as the Federal Water Pollution Control Act (PL 92-500).

California was one of the first western states to establish a permit system for the appropriation and diversion of water for beneficial use. That permitting process is now under the jurisdiction of the SWRCB. Permits specify a rate or quantity of water, the point of diversion, the uses to be made of the water, and the place of use. Generally, the user can divert the water and put it to any use, as long as the use is "reasonable" and not wasteful.

The two largest diversions of water from the delta are, of course, the SWP and the CVP. The permits issued by the SWRCB for the SWP and CVP facilities are in accord with Water Right Decision 1485 (D-1485),

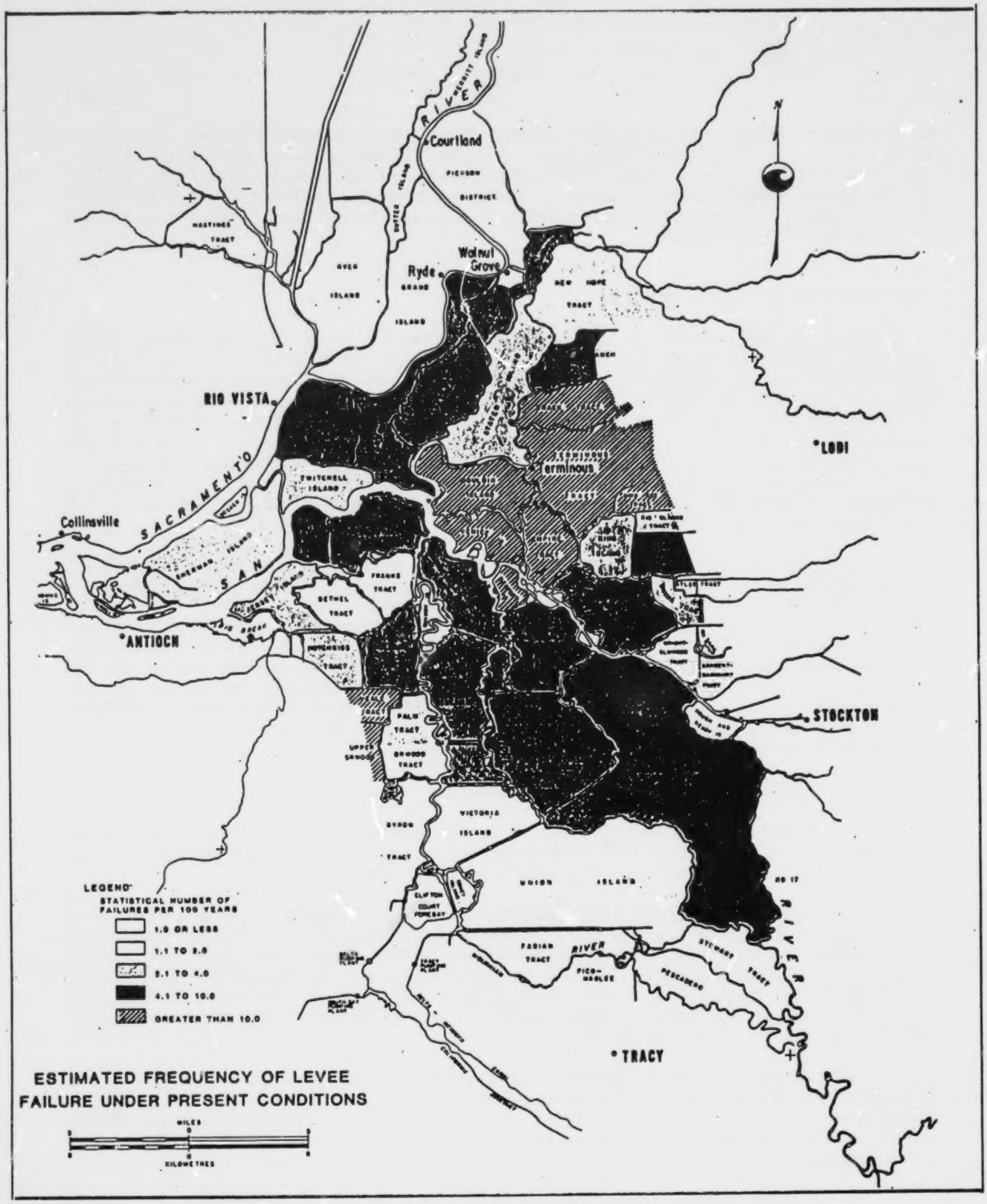
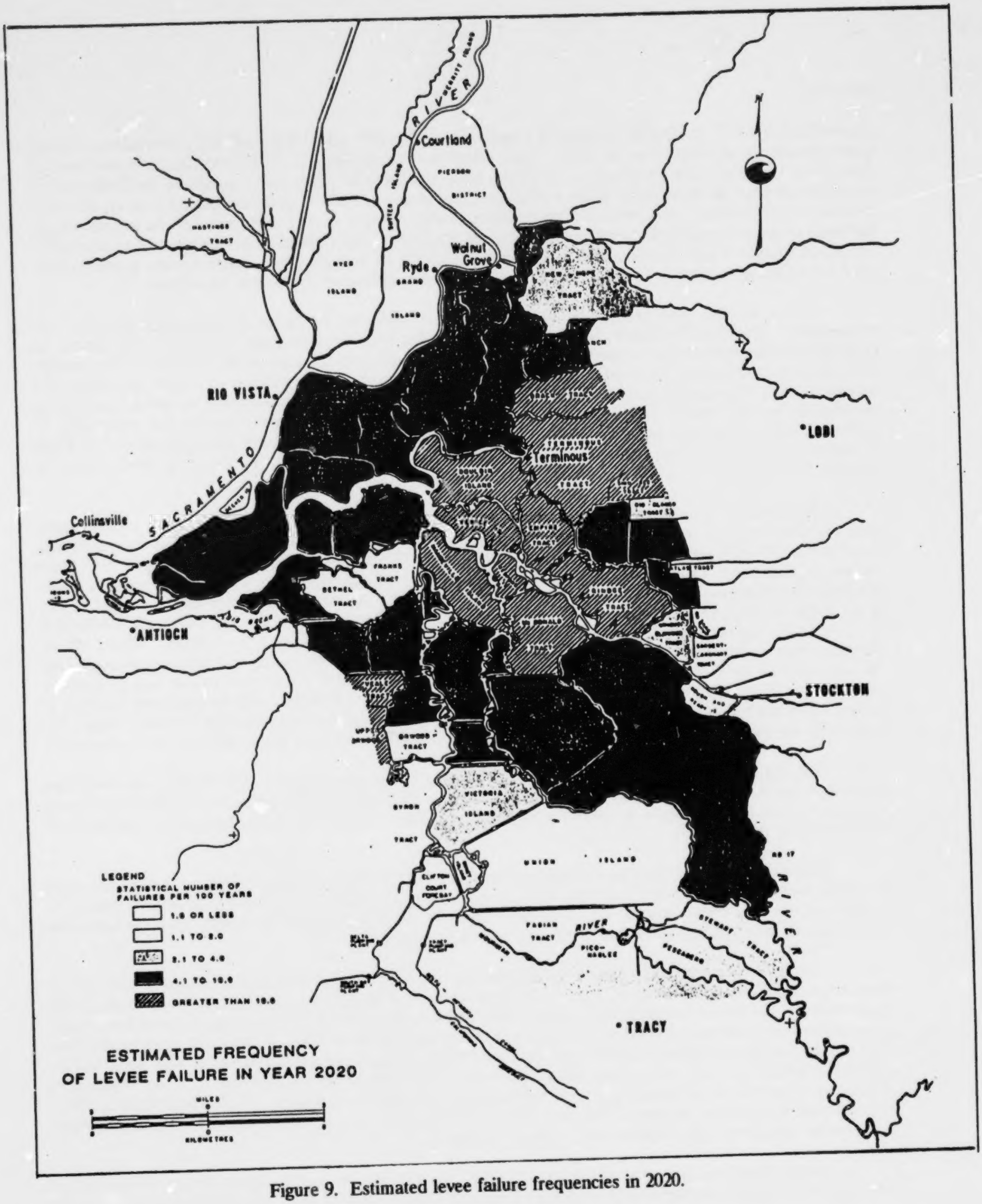

ESTIMATED FREQUENCY OF LEVEE FAILURE UNDER PRESENT CONDITIONS
LEGEND
STATISTICAL NUMBER OF FAILURES PER 100 YEARS
1.0 OR LESS
1.1 TO 2.0
2.1 TO 4.0
4.1 TO 10.0
GREATER THAN 10.0
MILES
KILOMETRES
N
RIVER
Courtland
PIERSON DISTRICT
SUTTER ISLAND
HASTINGS TRACT
RYER ISLAND
Ryde
GRAND ISLAND
Walnut Grove
NEW HOPE TRACT
RIO VISTA
Terminous
LODI
SACRAMENTO
TWITCHELL ISLAND
Collinsville
SHERMAN ISLAND
SAN
FRANKS TRACT
BETHEL TRACT
ANTIOCH
HOTCHKISS TRACT
PALM TRACT
ORWOOD TRACT
STOCKTON
VICTORIA ISLAND
BYRON TRACT
UNION ISLAND
CLIFTON COURT FOREBAY
FABIAN TRACT
RIVER
PICO-NAGLEE
PESCADERO
STEWART TRACT
TRACY
RIVER

Figure 8. Current estimated frequency of levee failure.



RIVER
Courtland
PIERSON DISTRICT
SUTTER ISLAND
HASTINGS TRACT
RYER ISLAND
Ryde
GRAND ISLAND
Walnut Grove
NEW HOPE TRACT
RIO VISTA
LODI
Terminous
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BOULDIN ISLAND
EMPIRE TRACT
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Collinsville
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RINDGE TRACT
McDONALD TRACT
STOCKTON
ORWOOD TRACT
VICTORIA ISLAND
BYRON TRACT
UNION ISLAND
CLIFTON COURT FOREBAY
FABIAN TRACT
RIVER
STEWART TRACT
RIVER
TRACY
LEGEND
STATISTICAL NUMBER OF FAILURES PER 100 YEARS
1.0 OR LESS
1.1 TO 2.0
2.1 TO 4.0
4.1 TO 10.0
GREATER THAN 10.0
ESTIMATED FREQUENCY
OF LEVEE FAILURE IN YEAR 2020
MILES
KILOMETRES

Figure 9. Estimated levee failure frequencies in 2020.

adopted in August, 1978. D-1485 requires as a condition in the SWP and CVP permits the maintenance of water quality standards as adopted in the "Delta Plan," except for the southern Delta (These standards are listed in Table II of D-1485). The underlying principle of those standards is "...that water quality in the Delta should be at least as good as those levels which would have been available had the state and federal projects not been constructed, as limited by the constitutional mandate of reasonable use. The standards include adjustments in the levels of protection to reflect changes in hydrologic conditions" experienced under different types of weather conditions (Water Right Decision 1485, SWRCB, 1978, emphasis added). Thus, there is some possibility left open for adjusting standards if climate conditions make them difficult or impossible to achieve.

When D-1485 was issued, the SWRCB stated it believed the level of protection afforded was "reasonable." However, the Board also recognized the possible need to revise these standards in the future. In keeping open the possibility of future changes, "the board...recogniz(ed) the uncertainty associated with possible future project facilities and the need for additional information on the complex effects of project operations and varying water quality conditions in the Delta and Suisun March." The Board also stated its intent "...to reopen the hearing on this matter within eight years from the adoption date, depending upon the availability of additional information upon which to re-examine these standards." Those standards are currently (not in 1986, as originally intended) being reviewed at the Bay-Delta Hearing in Sacramento. The hearing, which started in mid-1987, is expected to take several years to complete.

In summary, D-1485 requires that water quality standards in the Delta be satisfied prior to any export from the Delta to other areas for any purpose. The decision, which binds the federal CBP to the permitting terms of the SWRCB, was issued by the U.S. Supreme Court in California v. United States on July 3, 1978. This decision declared that a state may impose any condition on control, appropriation, use, or distribution of water in a federal reclamation project that is not inconsistent with clear congressional directives on the project. Thus, in the event of rising sea level and possible further penetration of saline water into the Delta, the SWRCB is likely to be the agency responsible for maintaining or changing Delta water quality standards. There will be pressure from environmental groups, such as the Environmental Defense Fund, and resource management agencies, such as the California Department of Fish and Game, to maintain these standards as high as possible. On the other hand, CVP and SWP users and managers might seek a relaxation of the standards in order to extract water from the Delta, especially if runoff decreases, or as discussed in the section on water supply, the seasonality of runoff changes and some form of additional lower-basin or even below-delta storage is necessary.

San Francisco Bay Conservation and Development Commission (BCDC). The BCDC was established as a temporary state agency with the passage of the McAteer-Petris Act of 1965. The tasks of the BCDC were to prepare a plan for the long-term use of the Bay and to regulate development in and around the Bay while the plan was being prepared.

The San Francisco Bay plan, completed in January 1969, includes policies on issues ranging from ports to public access. In August 1969, the act was amended to make BCDC a permanent agency, as well as to incorporate the Bay Plan's policies into state law. In 1977, the Suisun Marsh Protection Plan expanded the Commission's authority to include the protection of Suisun Marsh.

The BCDC's responsibility in the Suisun Marsh Protection Plan includes at least an assessment role in the matter of salt water intrusion. A recent BCDC report focused on several engineering steps for dealing with sea level rise: "Salt water intrusion will require additional structures and diversion canals to move fresh water form farther upstream into the marsh. Pumps will be required to drain many of the duck clubs as sea level rises". But, the report suggested that "...the outboard levees, constructed on compressible peat soils, will be subject to subsidence and overtopping from high water. Although it may be feasible from an engineering standpoint to protect the managed wetlands, the economic cost may be very high" (Moffat and Nichols, 1987). It is not clear at this time, however, what final role the BCDC might play in policy response to either salt water intrusion or even levee failure given future climate change.

Suisun Resource Conservation District (SRCD). The principal regulatory agency in matters pertaining to Suisun Marsh water management is the Suisun Resource Conservation District. The SRCD has primary local responsibility for "regulating and improving water management practices on privately owned lands within the primary management area of the Suisun March in conformity with Division 19 and the Suisun March Protection Plan." These powers are conferred to the district in Section 9962, Chapter 12 of Division 9 of the California Public Resources Code.

The main concerns of the SRCD regarding rising sea level and climate change are typical of most Delta organizations: salt water intrusion (coping with this problem is probably the district's main reason for existence) and levee failure. Also, most of the managed wetlands of Suisun March are drained by gravity/tidal gates. Rising sea level would make such tidal gates useless and likely turn Suisun Marsh into a tidal wetland.

The SRCD is party to the "Suisun Marsh Preservation Agreement." Other signees are the DWR, Bureau of Reclamation, and the California Department of Fish and Game. Also known as the "Four Party Agreement," this document effectively binds these agencies to a set of mutually acceptable water quality standards. In short, it assures that the DWR and Bureau of Reclamation will supply carriage waters to the Marsh to mitigate the adverse effects of SWP and DVP water use.

Water Delivery Agencies. As the managers of the two largest water delivery systems in the state, the U.S. Bureau of Reclamation and the state Department of Water Resources have a strong interest in possible sea level rise and its potential impact on Delta water quality--a significant increase in salinity levels in the southern Delta could render that water unacceptable to SWP and CVP contractors. The agencies can combat increasing salinity levels in two principal ways: 1) increase releases of upstream carriage waters, or 2) reduce water withdrawals from the southern Delta. As both of these options decrease the amount of water available to users farther south, neither is particularly desirable, especially in the SWP where supply and demand are more closely balanced than in the CVP. Yet, both agencies are obligated by D-1485 to meet water quality standards in the Delta and Suisun Bay, and their Coordinated Operations Agreement now specifies that they will share resources and facilities to meet carriage water needs.

Another possible impact of rising sea level is the inundation of the pumping plants and water supply systems operated by the Bureau and the DWR. Such a crisis might very well crystallize pressure for decisive action aimed at either maintaining the Delta as currently configured or for restructuring the water delivery system, perhaps through a circum-Delta canal.

Summary: Water Quality Will Be A Priority In Future Climate Adjustments

There are several possible responses to increasing salt water intrusion into the Delta caused by climate change, including the key options listed in Table 4.

First, it may be reasonable under certain circumstances to surrender to a more brackish Delta and plan to obtain the most benefits from this change (the "inaction" option). This would probably lead to a larger extent of Suisun Marsh-like environment, with benefits ranging from increased wildlife habitat, recreational opportunities, and possibly even commercial fisheries. The release of carriage flows is one of the principal ways in which salt water intrusion is presently combated. However, there is little water which could be dedicated to such an increase without affecting CVP and SWP users. Thus, option 2 would likely require large additions to upstream storage and transport capacity. This option faces many barriers: large capital expenditures during a period in which federal support for water development is declining, the reduction of acceptable sites on which to construct large storage facilities, and increasing pressure (especially from environmental groups) to prevent new on-stream storage facilities.

Reduced water withdrawal for export to southern California (option 3) has an obvious implication especially for the SWP: the project may not meet current and projected contract demand unless new sources of water can be found or efficiency can be dramatically increased, as discussed in the supply section above.

Table 4. Options for Adjusting Water Quality Management to Climate Change

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1) **Inaction:** This would include plans to derive the maximum benefits from a new salty marsh/brackish ecosystem.
2) **Increase carriage flows:** Increasing the releases of upstream water stored by the CVP and SWP.
3) **Reduce withdrawals**, especially those of the CVP and SWP, in the Southern Delta.
4) **Enlarge channels and waterways:** This would have the effect of increasing Delta flows, as well as reducing reverse flows during dry periods.
5) **Construct an isolated channel:** Such a canal would route water from the Sacramento River, around the Delta periphery, and directly to the export pumps near Tracy. Such a project, the "Peripheral Canal," was proposed in 1982 and soundly rejected by voters, especially northern Californians.

The various project improvements outlined in the latest update of the state's water plan, especially those which would improve the transfer of water across the Delta (including dredging of existing channels, channel enlargement, and new connecting channels) would not directly repel encroaching salt water, but would help maintain better southern Delta water quality by feeding the southern Delta pumping plants more efficiently. Thus, it may take some pressure off both carriage water requirements and raw water needs in the major delivery systems.

The fifth option, construction of an isolated canal to carry water from the Sacramento River directly to the southern Delta pumping plants, is not likely to be implemented in the near future because it would fall prey to the same environmental concerns that recently killed the Peripheral Canal proposal. However, if the Delta were to be threatened with conversion into a saline inland sea, such an alternative might be reconsidered.

The diversity of interests surrounding the Delta suggests that policies responding to climate impacts will be hotly debated. The large water delivery agencies are reluctant to increase carriage flows or reduce withdrawals. Options such as the enlargement of Delta channels or construction of an "isolated canal" are extremely controversial, though the latest state plans for these actions have elicited less criticism than most water managers expected. The salinity control plan, which should eventually emerge from the Bay-Delta Hearing, will be central to the choice of future options.

Delta water requirements will continue to be a key response policy issue in California water supply in the short and long term. A combination of natural Delta degradation and subsidence, sea level rise, and runoff changes suggested in the larger EPA study would require significant changes in water management over the next few decades. Currently, however, it appears that most of the policy options favor maintaining the existing system as long as possible rather than adjusting to climate change.

CHAPTER 3

CONCLUSIONS: WATER RESOURCE MANAGEMENT POLICY IMPLICATIONS OF CLIMATE CHANGE IN THE CALIFORNIA STUDY AREA

This analysis describes the key water resource management policies and practices that would be stressed by climate change in the California case study area. The three focuses--water supply/flood control, Delta island maintenance, and Delta water quality--are related and interactive. For example, changes in supply or flood control policy affect the ability to maintain water quality. Thus, the full range of agencies and interest groups listed in Table 1, and a wide range of resource management policies, will come into play as the region adjusts to future climate changes. Although the goal was to examine current policies, their climate sensitivities, and the range of options for adjusting policy in each area, the foregoing discussion points to a few speculative prospects for future adjustment.

PROSPECTS FOR POLICY ADJUSTMENT IN WATER SUPPLY AND FLOOD CONTROL

Water development trends in California could be characterized as actually quite predictable. Although economists have speculated on the emergence of "water markets" and a greater private role in large-scale water development, the latest manifesto from the state, its 1987 "Future" publication (California Department of Water Resources, 1987), outlines a plan for somewhat smaller developments that generally move the system farther along the previous development trajectory marked by public financing and management, and improved physical facilities. The report offers a set of scaled down physical improvements for increasing firm yield by 1 to 2 maf over the next two decades. Included in this package are improvements in existing transfer facilities in the Delta, development of offstream storage at the Los Banos Grandes reservoir, water banking in aquifers (such as the Kern Water Bank, a large groundwater storage project), and plans for the Los Angeles area to receive more Colorado River water, thus taking some pressure off of northern California supplies.

In short, expected demand will be met by increasing facilities and new sources or storages, although future management will probably be more open to increased levels of risk of occasionally failing to meet peak demand (a variable risk policy). By maintaining a closer relationship between supply and demand (i.e., less "excess capacity"), the system will continue to be sensitive to climate fluctuations, and managers will have to improve their fine-tuning of allocation rules. Calls for improved seasonal climate forecasting in the 1987 report illustrate the perceived need to better anticipate climate shocks.

Flood management in the basin is undergoing a major review by the USACE in light of apparently increased flood potential. After the 1986 floods, it was suggested that the proposed Auburn Dam was needed more for flood control than for water supply, and recent discussions have focused on an Auburn Dam built as a "dry dam" (what is typically called a "detention dam" in flood control planning) used only to hold peak flood waters and then emptied as soon as downstream conditions permit (Sacramento Bee, March 4, 1988). Thus, the dam would not create a large onstream reservoir. If current flood safety levels are to be maintained in the basin, some further tightening of operating rules--or additional flood storage--will be needed. Water management in the area will certainly be affected by the findings of the flood system review now under way.

There is, however, one event in the recent policy history of the area that portends a flexibility in adjusting to environmental uncertainty: the coordinated operations of the SWP and CVP. Water systems in the United States have tended to operate independently, each assuring its own firm yield by developing independent supplies and storage. But the tightening relationship between demand and supply in northern California, and differences in the capacity of the two systems, yielded a new joint operating policy that could act as a model for increasing the flexibility of water systems elsewhere and for further adjustment in the regions.

Indeed, the SWP/CVP Coordinated Operations Agreement (COA) represents, in many ways, a public policy response to climate sensitivity and the creation of a mechanism for absorbing future climate changes as it better distributes the "absorptive capacity" or excess capacity in the system. The chief goal of the COA was to share responsibility for passing through the water necessary to meet state-imposed Delta water quality criteria. This carriage water requirement has been growing since Decision 1485 (discussed in detail above) mandated that water operators permit enough water to pass on to the Delta to fight salt water intrusion. The increase has been due to a greater frequency of dry years in the basin since the mid-1970s, as well as degradation of the Delta's island-levee system. Chiefly by virtue of its larger excess capacity, the CVP takes up the slack in SWP carriage water deliveries and thus helps the SWP meet user requests when Delta requirements are high, runoff is low, or both. Most accounts suggest that the COA has helped the SWP avoid shortages in the past few dry years (1986-87 was another "critically dry" year in northern California). The COA clearly represents the kind of new, but simple low-cost, institutional relationships and policy tools that can help resource agencies absorb some climate change without drastic crisis responses or a rush to develop new physical facilities. Furthermore, the 1987 water plan update suggests that further coordination, perhaps even state management of both systems, is being considered.

Other than the COA, however, there is little evidence that less traditional adjustments, like the development of water marketing, will emerge in the near future.

PROSPECTS FOR ADJUSTING DELTA ISLAND LAND USE

The maintenance of the system of Delta islands and levees (or employment of the "strategic inundation" strategy) in the face of sea level rise will not as easily yield to incremental, operational adjustments as will supply and flood control. Indeed, Delta maintenance will be a costly policy even without sea level rise or reduced freshwater flows. In the face of either or both of these future climate trends, though, the public investment to protect the Delta islands could escalate dramatically. In the DWR's 1982 Delta Levee Investigation, then-DWR director Ronald Robie estimated "...a complete rehabilitation of the Delta levee system would cost a staggering $3.4 billion" (California Department of Water Resources, 1982).

The levee system is not in good condition, as evidenced by the 24 levee failures since 1980. The islands of the Delta, most of which are well below sea level, continue to subside as the Delta's peat soils erode and decompose. Nevertheless, short-term maintenance of the levee system, although very expensive, is viewed as quite feasible by most responsible agencies and other interests. There is a widespread attitude that because of the Delta's critical importance to California's water supply system and, subsequently, the entire state, its short-term maintenance is perhaps economically justifiable. In the long-term (i.e., greater than 50 years), however, maintenance of the levees is questioned even by some groups that support their rehabilitation now.

Despite the Legislature's recognition that "...it may not be economically justifiable to maintain all the Delta's islands...", there is an increasing potential for huge financial commitment to the maintenance of the Delta island system, especially in the face of rising sea level. Rising sea level will increase the failure of levees and promote the intrusion of salt water into the Delta. The possible disappearance of a fresh water Delta in the long run would drastically alter the character of the state's water supply system. Ideas such as the Peripheral Canal (which reappeared as an "isolated canal" in the state's 1987 water futures assessment, see California Department of Water Resources, 1987), soundly rejected by the voters in 1982, may not seem farfetched in the face of Delta inundation.

PROSPECTS FOR WATER QUALITY MAINTENANCE

Any decrease in managed water supplies (or even marked changes in the seasonality of runoff) in the Sacramento-San Joaquin Basin will further worsen Delta water quality unless the major delivery systems can provide more carriage water. Right now it appears that regulatory water requirements will take precedence over deliveries to users, though this is by no means assured in the face of cumulative climate change. It may be, however, that the large body of regulatory policy aimed at protecting water quality--which is not matched in water supply--may win out in future conflict for water that becomes more scarce due to climate change. However, it is not prudent to speculate on prospects for this issue until the Bay-Delta Hearings end. New attitudes, policy tools, and institutions may then emerge.

THE NEED FOR INTEGRATED POLICY SOLUTIONS

The proliferation of interests and institutions focused on parts of what is, essentially, a connected constellation of climate-sensitive policy issues in Northern California, suggests that near-future climate change could elicit a disjointed policy response. Yet the climate problem could also create new ties between resource management areas. For example, the coordinated operations agreement between the SWP and CVP represents a major policy adjustment to environmental uncertainty (e.g., variable and likely increasing requirements for carriage water to maintain Delta quality, and short-term climate fluctuations) that could act as a policy model for adjusting to other impacts of climate change. Indeed, additional interagency cooperation has been proposed in the state's latest water planning document, but no strategy has yet emerged to offer an integrated response to the interacting problems of supply, flooding, quality, and Delta protection, which could be exacerbated by almost any nontrivial magnitude or direction of climate change.

The old standard for integrated resource management policy in an area was the concept of watershed planning. Perhaps, given the emerging threat of climate change, there has come a need to incorporate climate-sensitive resource management practices.

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EFFECTS OF GLOBAL WARMING ON THE GREAT LAKES: THE IMPLICATIONS FOR POLICIES AND INSTITUTIONS

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Global climate change could have significant effects on the Great Lakes. According to studies sponsored by the U.S. Environmental Protection Agency (EPA), these impacts would include increasing temperatures, reduced runoff, declines in lake levels, and declines in snow and ice cover.

Natural and economic resources of the Great Lakes basin, especially those associated with the Lakes, would change. Studies prepared for the EPA indicate that water quality in the Lakes may decline. Lake bottoms would be exposed by falling water levels. Fisheries, forests, and agriculture would be altered. Costs of generating electric power and for navigation on the Lakes would increase. Tourism would change.

The Center for the Great Lakes found that changes in Great Lakes policies and institutions would be needed to adapt to these impacts. The International Joint Commission's regulations controlling outflows from Lakes Superior and Ontario would need to be updated. Water supply planning efforts presently underway under the Great Lakes Charter could, if successful, provide a basis for management of climate change's impacts to surface waters. Controlling impacts to groundwater would be harder.

The objectives of the Great Lakes Water Quality Agreement would need to be reevaluated, and new discharge standards and expensive new treatment works would be required to maintain water quality. Non-point source impacts could be very difficult to control.

It is not clear who would own the new shorelands exposed by receding lake levels. Conflicts over management of these bottomlands and other public lands would increase. The long tradition of local control in land use would make it very difficult to coordinate adaptations to climate change on private lands.

If these impacts to water and land resources can be managed successfully, the region's abundant water supplies could provide a competitive advantage in attracting economic development. However, significant changes would occur in many key sectors, including power generation, agriculture, forest products, tourism, and navigation. Strong regional institutions capable of coordinating public policies which adapt to these changes are found only in the forest products sector, where state and national forest planning can help prepare for climate change's effects.

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CHAPTER 1

INTRODUCTION

A consensus is emerging among world scientists that increasing concentrations of carbon dioxide (CO2), methane, nitrous oxides, and chlorofluorocarbons (CFC's), plus other "greenhouse" gases in the earth's atmosphere could change world climate. In preindustrial times, CO2 was 280 ppm; today, the count stands at 340 ppm. Burning of fossil fuels, increased agriculture, deforestation, and the introduction of CFC's have increased concentrations of greenhouse gases in the atmosphere. By 2060, if emission trends remain constant, the cumulative impact on climate would be equivalent to doubling CO2 concentrations.

Most models of the earth's atmosphere predict increases in world temperature under higher CO2 concentrations -- from 1.5°C to 4.5°C. Mean global temperatures have increased about .5°C over the last century -- within the range predicted if the greenhouse effect is on the rise. It is too soon to tell if unusual global warming has begun because of the natural variability of climate and because any excess greenhouse warming would be masked for some time by the enormous absorbing capacity of the oceans.

How might these changes influence the Great Lakes, the largest body of freshwater in the world? The Lakes hold 18 percent of the planet's surface freshwater. They are fed by the runoff from over 500,000 square kilometers of forests and farmlands. Approximately 37 million residents find their home on the Lakes' 16,000-kilometer-long coastline. The basin is the industrial center of North America -- accounting for 37 percent of the value added in U.S. manufacturing and half of Ontario's industrial production. The basin's residents and industries depend on the Lakes for water supplies, recreation, and navigation. The region's governments and United States and Canadian agencies have invested billions of dollars in conserving and developing the Lakes' resources through the control of pollution, the development of water supplies, the purchase of park lands, construction of harbors and navigation channels, and other actions. How will global climate change affect the basin's industries and residents and the Lakes upon which they depend?

Although effects are far from clear, scientists have begun to identify some potential regional impacts from global climate change. In the Great Lakes basin, these impacts could include an increase in average temperatures, an increase in evapotranspiration, a decline in ice cover, and related reductions in lake levels and stream flows. If these impacts occur, profound changes in the region's environment and economy would follow. Water supplies for municipalities, industry, and agriculture could be reduced, and the quality of water in the Lakes and their tributaries could decline. Fisheries and recreational opportunities would be altered. Resource industries like agriculture and forestry that sustain rural economies could be transformed. Commercial navigation through the ports and navigation channels which served the Lakes could be limited by low water levels.

For managers and users of the Great Lakes, a question arises: Could the Great Lakes' community adapt to these potential global climate change impacts on the basin? This study looks at that process of adaptation and examines the strengths and weaknesses of the Great Lakes region in responding to global warming. It is one of a series of global climate change regional impact studies commissioned by the U.S. Environmental Protection Agency (EPA) at the request of Congress.

The report describes the methods used in the study. It reviews today's policies and institutions for managing these Great Lakes resources. The report then summarizes other research to describe how the Great Lakes environment and economy could be affected by global climate change. It suggests how these policies and institutions might respond to climate change in the region. Finally, the report recommends actions to assist in developing a regional response to potential climate alterations.

CHAPTER 2

METHODOLOGY AND SCENARIOS

This study began with a description of the present policy and institutional framework for managing four attributes of the Great Lakes region -- water supply, water quality, land use, and the economy. The description -- based on studies by The Center and others -- is summarized in Chapter 3 of this report.

The Center then reviewed U.S. and Canadian studies of global warming. Climate change scenarios provided by the EPA formed the basis for analysis of the potential impacts of climate change. Researchers on global climate change's regional impacts have used these scenarios as inputs to their models. These regional investigations, funded by the EPA and Environment Canada, generally use "off-the-shelf" models of the relationship between climate and their analytic area. For example, the Great Lakes Environmental Research Lab has used its hydrologic model of the Great Lakes to study possible impacts of climate change on lake levels. Chapter 4 of this report recaps investigations of the effects of climate change on the Great Lakes' environment and economy. In some cases, these results were augmented by inferences drawn by The Center based on related impacts reported by other researchers.

With these summaries in hand, The Center brought together policy experts, community leaders, and business people from around the region to examine these potential impacts of climate change. Participants were selected based on their expertise with regional policy and institutions. Prior to the meeting, The Center mailed each participant a copy of The Center's summary documents and a questionnaire to assist in their preparation for the workshop. Seventeen study participants, listed in Table 1, met in Chicago on May 5, 1988 and discussed the implications of global climate change for the region. Workshop participants were asked to identify the Great Lakes management policies and institutions most affected by climate change, to forecast how these policies would be affected by climate change, and to analyze the ability of Great Lakes' institutions to develop and carry out policy modifications that respond to climate change. We also asked workshop participants to recommend appropriate steps to prepare Great Lakes policies and institutions for the potential of climate change. The consensus of their comments is summarized in Chapters 5 and 6 of this report.

There are many assumptions and uncertainties which influence this study. The uncertainty is not with the trend in increasing atmospheric greenhouse gases, but with the impact of this change on the Great Lakes. Results from climate models are very tentative estimates of future climate for a specific area. Forecasts of impacts on specific resource components are hampered by the imprecision of the climate models, their limited ability to consider interactions between resource categories or changes in resource models through time, and other factors. This variability is compounded in a survey such as this, to which seventeen participants bring their own model of how Great Lakes policy is made and implemented. At the least, the results identify impacts of climate change most sensitive to policy choices made in the region, and suggest some of the region's strengths and weaknesses as it begins to address climate change.

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CHAPTER 3

EXISTING POLICIES AND INSTITUTIONS FOR MANAGING THE GREAT LAKES' ENVIRONMENT AND ECONOMY

The policy and institutional framework for management of the Great Lakes reflects the scale and complexity of the Lakes themselves. The system is a multipurpose resource shared and managed by two federal governments, eight states, two provinces, and hundreds of local agencies. Several international organizations attempt to coordinate the development and implementation of management policies in the basin.

Several broad trends unify these organizations' development and implementation of policies in the region. The first of these is the "ecosystem concept" of Great Lakes management -- the recognition of the interrelatedness of resources in the Lakes' basin. A growing sense of regionalism, characterized by the formation of the Council of Great Lakes Governors and the increase in coordination between the Lakes' states and provinces, reflects this ecosystem approach. In the U.S., the "new federalism" has increased the trend toward regionalism as states and localities pool resources to deal with common problems previously handled by federal agencies. Demands on regional organizations are increasing, while the complexity of the resource and economic challenges confronting them grows (Donahue, 1987).

The foremost of these regional institutions, the International Joint Commission (IJC), is a binational agency created by the Boundary Waters Treaty of 1909 to prevent disputes regarding use of waters along the U.S.-Canadian border. The IJC has potentially broad authority to investigate issues affecting the Lakes, recommend policies for lake management, and resolve disputes related to lake levels and water pollution. In practice, a number of factors limit the IJC's influence. First, the IJC exercises these powers in response to requests from the federal governments, usually in a reactive, not a proactive fashion. Second, state, provincial, or local governments are not represented on the IJC and feel they have limited access in its decision making. As a result, these governments have often not involved the IJC in regional decision making. Some important decisions affecting the Great Lakes have also been made directly by the two governments with little involvement from the IJC. Finally, while the IJC has demonstrated the ability to utilize technical information in developing policy recommendations, it has no independent ability to enforce its judgments, and its advice is often ignored by the two governments and other regional jurisdictions (National Research Council, 1985). Donahue (1987) found that many observers recognize the Commission's "unrealized but available potential as a potent force in Great Lakes management."

Other regional institutions have had mixed effect in developing and implementing policy. The Great Lakes Commission, an organization created by compact among the Great Lakes states, lacks participation from Canadian provinces. In the past, the Commission's small staff has left it with limited abilities to plan or use technical information in policy development. Its commissioners have weak links to key state decision makers. As a result, the Commission has not been active in policy development, but has served more as a forum for interstate discussions and a vehicle representing the region's collective presence to the Congress.

Other coordinative functions are undertaken by the Council of Great Lakes Governors and related associations, such as the Council of Great Lakes Environmental Administrators and the Council of Great Lakes Research Managers. These entities encourage collaborative efforts on common problems and help coordinate implementation of shared policies. The Great Lakes Charter (see discussion of water supplies below) is one product of these entities' growing skills at policy development. The long-term efficacy of these institutions in implementing the policies they announce has not yet been demonstrated.

These entities, together with national agencies and state, provincial, and local governments, have developed a complex network of policies and institutions to manage the Lakes and their watershed. Four elements of these management efforts -- water supplies, water quality, land use, and economic development -- are particularly key in developing a regional response to global climate change.

WATER SUPPLY

Water has been abundant in the Great Lakes, so the framework for managing water supplies in the basin is still developing. The earliest efforts to manage water supplies were conducted by the IJC and focused on controlling lake levels to protect municipal supplies, maintain navigation, and promote hydroelectric development. Now a new effort, initiated by the states and provinces, is regulating consumptive uses of the Lakes' water and leading toward development of a coordinated water supply management program for the Lakes. These efforts are driven by increasing water use in the basin and by concerns that the region could be harmed by diversion of Great Lakes waters to users outside the basin. Management of surface and ground waters is not well coordinated.

Water levels in the Great Lakes fluctuate with annual and seasonal variations in rainfall, runoff, and precipitation. The difference between extreme high and low annual water levels is about 2 meters. Physical works for managing Great Lakes water levels are not extensive. Regulation of outflows through locks at the Saint Mary's and St. Lawrence Rivers has been designed to balance the interest of those affected. For example, the present plan regulating outflows from Lake Ontario to the St. Lawrence River incorporates criteria reflecting the needs to maintain shipping in Quebec and the St. Lawrence Seaway, minimize spring flooding in the St. Lawrence Valley, maximize dependable flows for hydropower production, and reduce damage to Lake Ontario shoreline landowners from extremes in lake levels (International Joint Commission, 1973). The regulations take into account existing diversions into the basin at Long Lake and Ogoki and out of the basin at Chicago and the Welland Canal, which only affect lake levels by three to four inches (Sea Grant Institute, 1988). While several large-scale schemes to divert Great Lakes' water to lower lake levels for erosion control or to serve users in other basins have been proposed, none has received substantial support.

Surface waters supply 95 percent of the basin's water needs. The remaining supplies come from groundwater. Present consumptive water use in the basin, estimated at 2900 cubic feet per second (cfs) to 5600 cfs, is projected to increase 50 to 96 percent through the year 2000 (Solley et al., 1983; International Joint Commission, 1985) Almost 90 percent of the water consumption in the basin occurs in the U.S. Canadian water demands are increasing slowly. In the year 2000 total water consumption is estimated to increase to 9,980 cfs, of which 85 percent will be consumed by the U.S. (Sea Grant Institute, 1988).

Water supply policy in the Great Lakes has been influenced by four primary institutions: the Boundary Waters Treaty of 1909, federal water laws, state and provincial water law, including the Great Lakes Charter, and the municipalities and industries who develop facilities for consumptive use of water. The Boundary Waters Treaty between the United States and Canada regulates lake levels and diversions in the waters of the U.S.-Canada border (Cohen, 1982). The treaty granted the International Joint Commission the power to approve or disapprove any diversion or use of boundary waters which would affect the level and flow of the boundary waters (Fairley, 1982). In reviewing applications which may affect water levels and flows, the IJC is guided by the following priorities:

1. Uses for domestic and sanitary purposes,
2. Uses for navigation, including canal service,
3. Uses for power and for irrigation purposes.

The Commission has the authority to authorize a diversion plan conditional upon remedial or protective measures being constructed (Sugarman, 1986).

Some elements of the 80-year-old treaty limit its value in addressing contemporary water management problems. Its priorities for water allocation, for example, do not consider concerns such as environmental protection or the needs of recreation and water-using industries which have developed in the last few decades. In addition, the IJC lacks authority to regulate small-scale diversions and consumptive uses which are individually minor but cumulatively significant (Fairley, 1982) and may not address Lake Michigan or other tributaries which are not boundary waters. The IJC cannot act independently to resolve water use disputes. Implementation of its decisions depends upon the consent of both the U.S. and Canada.

U.S. federal water law also influences the regulation of lake levels and diversions on the Great Lakes. A clear U.S. national water policy has not been defined by the Congress. Instead, a small body of case law guides federal decisions about water supply, development, and allocation. In the most important federal case, Wisconsin v. Illinois, the U.S. Supreme Court ruled that Illinois must restrict diversions from Lake Michigan to the Mississippi River, limiting the amount of water to be diverted from the lake in order to prevent damage to water supplies required by other basin states (Council of Great Lakes Governors, 1985). In this and similar decisions, the court has applied the principle of equitable apportionment of interstate waters amongst the bordering states. Litigation in the case spans six decades. In other actions the U.S. courts have held that water is an article of interstate commerce (Sporhase v. Nebraska) which may only be regulated by states in an evenhanded way (City of El Paso v. Reynolds). State statutes banning the export of water to promote in-state economic interests have been struck down where the state could not also demonstrate that the sale of water would create a shortage threatening health and safety needs of the state (Tarlock, 1986). U.S. law also recognizes federal supremacy in matters affecting navigation.

State and provincial water rights laws have traditionally been based on common law doctrines of riparian right, under which all shoreline property owners share an equal right to the use of water from adjoining lakes and rivers. Recently, water supply policy in the basin has begun to move away from riparian rights towards a system where appropriation of water is regulated by the states to protect the public interest. In 1985 the region's governors and premiers signed the Great Lakes Charter, a program for coordinated management of Great Lakes water supplies. The Charter is a good faith agreement to pursue a common strategy for the protection and use of the Great Lakes. A primary principle of the Charter is that the use or diversion of Great Lakes water will be regulated by the states to prevent negative impacts on lake levels, other water uses, and the Great Lakes ecosystem. The governors and premiers agreed to seek legislation to implement the Charter in their jurisdictions and to disallow large water diversions without notice and consultation with other Great Lakes states and provinces. This change from a system of riparian rights to a program of state-regulated water appropriation reflects a growing view of water as a valuable public resource (MacAvoy, 1986).

The states' and provinces' progress in implementing the charter varies. Wisconsin's Water Resources Conservation and Management Act is typical of the states' implementing legislation. The law requires the state Department of Natural Resources to examine ground and surface water together as an integrated state water system. The act also requires the inclusion of boundary waters, such as the Great Lakes, in the state's water management programs. The law requires that withdrawals in excess of 100,000 gallons per day within a 30-day period must register with the DNR (Shea, 1987). Efforts to develop the basinwide coordinated water management program called for in the Charter are just beginning. Work to date has focused on development of a regional water use data base to be maintained by the Great Lakes Commission.

Groundwater management in the Great Lakes basin follows principles similar to those governing riparian rights. Where Great Lakes states have adopted laws to regulate groundwater use, they have frequently sought to mitigate disputes between farmers seeking protection of local water supplies and big cities that sink large wells in rural areas to develop new water supplies for their jurisdictions (Tarlock, 1986). The groundwater laws in many Great Lakes states do not yet recognize the hydrologic connection between surface and groundwaters. For example, very few Great Lakes states assess the impacts of groundwater pumping on streams and lakes overlying the aquifer.

WATER QUALITY

The basic water quality policies of the Great Lakes basin are incorporated in the U.S.-Canada Great Lakes Water Quality Agreement (GLWQA). The agreement's fundamental policies seek to:

1. Maintain Lakes Superior, Huron, and Michigan in the oligotrophic state, with low supplies of plant nutrients, little algae growth, clear waters, and low biological productivity.

2. Reduce nuisance algae conditions in Lakes Ontario and Erie, and restore year-round aerobic conditions in the bottom waters of the central basin of Lake Erie.

3. Virtually eliminate the discharge of toxic substances to the Lakes.

The GLWQA takes an ecosystem approach in setting water quality standards for the Great Lakes. For example, water quality plans being prepared under the agreement for each Lake and for 42 persistently polluted nearshore "Areas of Concern" recognize that achieving the agreement's goals depends on maintaining a chemical, physical, and biological equilibrium in the Lakes.

For nutrient control, the Great Lakes Water Quality Agreement uses the concept of mass balance -- the total amount of pollutant introduced to each lake -- to set water quality standards and recommend pollution controls. Because the treaty limits nutrient discharge based on the concentration of phosphorous in municipal wastewater, the U.S., with its larger population and greater volume of sewage effluent, is allowed a greater proportion of nutrient loading to the Lakes than Canada. For example, U.S. phosphorous discharges to Lake Erie are almost eight times those of Canada. The mass balance approach is not used to set water quality standards for toxics. Instead, the parties to the agreement promise to abate discharges of toxic chemicals from point sources, inventory progress in reducing point source discharges to the Lakes, and meet specific objectives for a variety of pollutants (The Center for The Great Lakes, 1987).

Under the GLWQA, the IJC is responsible for advising on water quality issues and reporting to the states and provinces on progress toward the achievement of the objectives in the agreement (GLWQA, 1978, 1987). While their advising and reporting plans for the Lakes provide guidance for state, provincial, and federal agencies (Cohen, 1982; Fairley, 1982), the IJC lacks authority to enforce its judgments. The slow pace of development of Remedial Action Plans is an example of the limits of the IJC's authority.

National, state or provincial, and local institutions implement the Great Lakes Water Quality Agreement and meet other water quality goals of their jurisdictions. These organizations typically address at least four water quality issues: point discharges, dredging, nonpoint source discharges, and areal deposition of pollutants. The Great Lakes Water Quality Agreement is recognized in the U.S. Clean Water Act (CWA), which establishes a Great Lakes National Program Office in the U.S. EPA and charges it with the responsibility for meeting U.S. commitments under the Great Lakes Water Quality Agreement.

In the United States, industrial and municipal wastewater discharges are regulated under the Clean Water Act (CWA). The CWA requires dischargers to obtain permits limiting the constituents and amounts of their wastes. The U.S. EPA approves each state's system for issuing National Pollutant Discharge Elimination System (NPDES) permits. The discharge of nutrients and toxic pollutants is regulated under the same effluent limitations in the Act. In Canada, the Canada Water Act provides for controls on nutrient discharge, while Ontario's provincial Municipal and Industrial Strategy for Abatement program will set standards for toxic pollutants.

In response to these water quality requirements, municipalities, special districts, and industries have upgraded, constructed, and operate extensive wastewater treatment facilities. Over $6.8 billion has been spent by state, provincial, and federal governments to improve municipal wastewater treatment since 1971. Cities and industries have spent a similar amount (Keating, 1987). As a result, industrial and municipal discharges of nutrients to the Lakes have been substantially reduced and approach the targets established in the GLWQA. The elimination of toxic chemical discharges, on the other hand, continues to elude industrial and municipal discharge regulators. A new clean water program, focused on eliminating toxic chemical pollution in nearshore "Areas of Concern," is now being prepared to address the problem. Implementation of cleanup plans for these areas will cost billions of dollars.

Dredging in many Great Lakes harbors and navigation channels creates water quality problems because the bottom sediments are contaminated by toxic chemicals. Water quality regulations, implemented by national and provincial or state agencies, require special dredging and spoils disposal techniques. Where dredging is permitted, these requirements raise harbor maintenance costs. In some harbors, sediments are so polluted that dredging is forbidden, and navigation uses have been harmed.

Nonpoint source pollution, including runoff of fertilizers and pesticides from farmlands, soil erosion, and the discharge of urban stormwater, has received less attention in Great Lakes water quality management. In the U.S., regional governments and states have developed plans for nonpoint source discharge control under Section 208 of the Clean Water Act. The plans recommend management practices for construction, forestry, agricultural, and other activities which generate discharges. In rural areas, state and federal agriculture departments and local soil or resource conservation districts implement soil erosion control programs by providing technical advice and government subsidies for soil conservation activities on private lands. Pesticide runoff is controlled by federal and state regulations which require that pesticides used must be approved by the U.S. EPA (Council of Great Lakes Governors, 1986). Nonpoint source controls have not been adequate to meet GLWQA pollution control targets (National Research Council, 1985).

Work to address aerial deposition of pollutants is just beginning. The GLWQA provides for joint U.S.-Canada programs to identify atmospheric sources of contamination. The U.S. Clean Air Act relies on pollutant-by-pollutant controls which are not designed to protect water quality against cross-media effects (The Center For The Great Lakes, 1987). An air toxics data base is currently being compiled by the U.S. EPA to monitor air emissions of toxic substances.

LAND USE

Most land use controls in the Great Lakes basin are developed and implemented by local governments. There are few requirements for coordination between jurisdictions or for accommodation of larger than local concerns. Federal and state land use controls primarily affect public lands such as forests, parks, and lake bottoms. Key land use policies influenced by climate change are those affecting lake bottoms, coastal zones and floodplains, vegetation management, including protection of sensitive habitats and prime farm lands, and community development.

In the U.S., lake bottoms to the ordinary high water line are the property of the states. Under the "public trust" doctrine, these lands must be managed for commerce, fishing, waterfowling, bathing, swimming, and boating. All the states regulate the use of lake bottoms to protect public property and assure that any private encroachments are consistent with the trust (Smith, 1982). The states have given little attention to long-term planning for the Lakes' bottoms.

Hazard reduction policies for Great Lakes' shorelines and floodplains are typical of the region's reliance on local governments for land use control. Only three of the Great Lakes states require development setbacks along erosion prone shorelines. In addition, the basin is not included in the U.S. coastal barrier system, a program which denies federal funds for development of designated erosion or flood-prone coastal barriers. These kinds of policies are only now under consideration in Ontario and the U.S. Congress. Structural solutions to coastal erosion problems remain popular with local governments and shoreline landowners. Three states provide financial assistance for the construction of coastal erosion control structures. Land use controls in floodplains are more common. Six of the Great Lakes states require that their local governments participate in the National Flood Insurance Program, and most shoreline counties have zoning which regulates development within the 100-year floodplains of rivers and lakes (The Center for the Great Lakes, 1988).

Major public land owners in the Great Lakes watersheds include the U.S.DA Forest Service (6 percent of U.S. watershed lands), state forestry agencies (6 percent of U.S. watershed lands), the province of Ontario, and national, state, and provincial park or habitat preservation agencies (Great Lakes Basin Commission, 1974). U.S. national forest lands are managed primarily for timber production, recreation, watershed protection, and fish and wildlife habitat. Long range plans for individual forests are now being developed by the U.S. Forest Service.

Most state forest lands are used for timber production and recreation. Parks and other habitat lands in the basin are managed for outdoor recreation and the protection of critical habitats, especially wetlands and old growth forests.

About 80 percent of the Great Lakes' U.S. watershed is privately owned. Most land use management decisions affecting these properties are made by individual landowners, subject to zoning and development regulations implemented by local governments. All the Great Lakes states and provinces authorize local governments to develop comprehensive plans for land development and to enact zoning ordinances and other development controls. Redevelopment of aging urban waterfronts and central cities is an important element of this land use planning effort (Center for the Great Lakes, 1986). There are few provisions for state review of local plans to assure that they reflect larger than local goals or are coordinated with neighboring jurisdictions. For example, only half of the Great Lakes states participate in the national coastal zone management program or control development of shorelines, wetlands, or other critical areas. Coordinated programs to conserve farmlands, protect aquifer recharge areas, or control urban sprawl are also lacking. Planning and land use regulation is weakest in rural areas. No state reviews major conversions of vegetation in rural lands, such as conversion of forest lands to crop lands, or regulates forest practices in commercial timberlands.

ECONOMIC DEVELOPMENT

The Great Lakes economy has been altered in the past decade. Population growth has stopped and basic industries have declined. Despite these changes, much of the region's economic activity continues to focus on Lake-related industries -- water-related manufacturing, electric power generation, tourism, and navigation. Agriculture and forest products are also key sectors of the region's economy. Most economic development decisions in the region are made privately. The important state and local government decisions seen as promoting economic growth are those affecting urban development and industrial siting, public utilities, transportation, and taxes. A host of recent state and local plans emphasizing training, technology development, marketing, and promotion of key industries may suggest a new era of government activism in economic development (SRI International, 1984).

The 1980's have seen substantial change, but little overall growth in the Great Lakes economy. Substantial losses in traditional manufacturing jobs have been equaled by gains in service employment. Population growth has lagged behind other portions of the United States. Population in the Great Lakes states is projected to increase by 4 percent by the year 2000, compared to a national increase of 11 percent (Kelly and Anthony, 1988).

Despite the restructuring of the recent years, manufacturing remains a central element of the Great Lakes economy, providing 23 percent of all payroll employment in 1984 (Federal Reserve Bank of Chicago, 1985). Water-intensive industries, such as primary metals, timber products, food processing, and chemicals are linchpins in a complicated system of mutually dependent industries in the region (Center for the Great Lakes, 1984). Industrial water use in the region is relatively efficient. While the region's states produced 42 percent of the value of U.S.-manufactured goods in 1982 (Federal Reserve Bank of Chicago, 1985), it accounted for only 15 percent of total nonpower self-supplied industrial water use in the U.S., and only 7 percent of the nation's consumptive nonpower self-supplied industrial water use (Solley et al., 1983). All but two percent of the self supplied industrial water use in the region's states is drawn from surface sources.

State and local policies aid these industries by planning and zoning lands for industrial use; by providing infrastructure such as water, wastewater, transportation, and other services; by offering tax and other incentives for new business development; and by focusing state research and development funds on key industrial sectors. Great Lakes states lack legislation providing for state review of major industrial siting decisions, leaving these activities to local zoning controls.

Electric power is a key element in the region's industrial production and the major user of Great Lakes' water. In 1984, the Great Lakes states produced 672,000 gigawatts of electric power -- 72 percent from coal- and oil-fired plants, 13 percemt from nuclear power plants, 9 percent from combustion turbine/internal combustion plants, and 5 percent from hydroplants. Concerns about nuclear safety, the difficulty in disposing of nuclear wastes, concerns about power plants' impacts on the Lakes, and competition from low-cost local coal have constrained expansion of nuclear generation in the region. Most power consumed in the basin is produced here. Only New York utilities, such as Niagara Power and the New York Power Authority, purchase more than 10 percent of their power needs from outside sources. These utilities obtain most of their outside power from Ontario (Jeffers, 1988). Power generation is the major use of industrial water in the region, accounting for 82 percent of self-supplied water use on the U.S. side of the region. Less than 0.03 percent of this water is consumed, compared to a U.S. average of 2 percent. In 1985, the International Joint Commission forecast that regional power production would increase 2.5 percent per year to the year 2000 in the U.S., and 2.1 percent per annum in Canada (International Joint Commission, 1985).

In the U.S., power plant siting is controlled primarily by utilities, by local governments through their planning and zoning powers, and by state utility commissions. Goals of these programs are to assure adequate supplies of power, maintain financial stability and profitability of utilities, protect consumers, and avoid land use conflicts. Neither the U.S. government nor the states review power plant siting decisions to promote a preferred mix of power sources or to implement an overall strategy of energy generation. Only half the Great Lakes states have a state-administered power plant siting process that includes environmental impact assessment (Duerksen, 1983).

Forestry and processing of forest products are major employers in the northern part of the region. In Wisconsin, for example, timber harvesting, wood-using manufacturing, and related industries provide 283,000 jobs (1985), ship $10.4 billion in wood products (1986), and rank among the top three employers in over half the state's counties. Key timber species are aspen, pines, balsam fir, spruce, maples, paper birch, and oak. Each state has a long-range plan which assesses demand and supply for forest products and makes recommendations for management of state and private forest lands. These plans are coordinated with an equivalent planning effort undertaken for national forests by the U.S.DA Forest Service. State and federal timberlands are managed to match production targets set to their long-range forest resource plans. The impacts of these planning efforts are reflected in the growing importance of wood products industries. In Wisconsin, for example, an average of almost $450 million was invested annually in the state's timber industry between 1982 and 1986, accounting for almost a third of the total new investment in industries in the state (Lindberg. 1988).

Agriculture provided $36 billion in cash receipts in the Great Lakes region in 1983 and is the largest single industry in the region. Production of major farm commodities -- corn, soybeans, and wheat -- is very sensitive to export markets, which produced 46 percent of the region's agricultural income in 1982-83. Surplus production of these commodities has depressed farm prices. Irrigated agriculture is not extensive. It occupied only 450,000 acres in 1980 (Solley et al., 1983). Agriculture in the region is strongly affected by national farm policies, such as subsidies to support farm income, assistance in farm financing, payments to encourage soil and water conservation, marketing assistance, and technical advice. Economic development plans in the region call for increasing the diversity of agricultural products produced and promote additional food product processing within the region.

Great Lakes navigation is important to grain producers and to steel and power production in the region. The system includes the locks and channels of the St. Lawrence Seaway and the Great Lakes connecting channels, 83 ports, and 210 merchant vessels, together with foreign flag vessels calling at Great Lakes ports. These facilities serve a hinterland which includes not only the Great Lakes states and provinces, but also the central and northern Great Plains states, Canada's prairie provinces, and the upper Ohio River valley. The shallow 7.9 meters (26 foot) depth of Great Lakes channels and ports cannot support modern ocean vessels. The length of passage required to transit the system, coupled with the winter ice, also discourage potential users. As a result, the navigation system is not a vital element of the region's export based manufacturing industries (Federal Reserve Bank of Chicago, 1985; Frankel, 1982). Instead, most manufactured exports and much of the region's agricultural exports are shipped by rail or inland waterways to coastal ports, leaving the Lakes primarily to lakewise shipping of coal, iron ore, stone, Canadian grain exports, and iron ore imports from Canada's Atlantic provinces (Ryan, 1982; Federal Reserve Bank of Chicago, 1985).

Public policy for the navigation system is dominated by the two federal governments, who have constructed and maintained the Seaway, other locks, and most port navigation channels, and provide ice control on the lakes. While the two nations have considered extended ice control to lengthen the winter shipping season, neither shows much enthusiasm for deepening of the ports and locks due to the high cost. For example, the cost of deepening U.S. facilities to accommodate ships drafting 9.7 meters (32 feet) was estimated at $4 billion (U.S.) in 1968, 1.5 times the two federal government's total investment in construction of the Great Lakes-St. Lawrence system between 1946 and 1970 (Great Lakes Basin Commission, 1975). Most land side facilities at U.S. and some Canadian ports are constructed by local port authorities, usually units of city government or districts specially authorized to carry out port functions. The ports are independent of the national governments which maintain the systems channels and locks, and compete amongst themselves for cargoes and related port revenues. The difficulty of coordinating policy among so many institutions limits long-range planning and collaboration in controlling the overall system.

Tourism has been an important component of the region's economy since the 19th century. The recreation industry includes resorts, restaurants, sport fishing boat operators, marinas, and boat builders. Estimates of revenue from Great Lakes-based tourism range from $8 billion to $15 billion in 1984. The 63 million people who visited park lands on the Great Lakes shores in 1983 are estimated to have spent $3.7 million. The Great Lakes Fishery Commission reported that 54.9 million angler days spent on the Great Lakes in 1981 generated $766.2 million (The Center for the Great Lakes, 1984). In urban areas, visitors are drawn to new marinas, parks, and redeveloped waterfronts, an increasingly common feature of Great Lakes city shorelines (Center for the Great Lakes, 1986). In the region's rural north, like Minnesota's North Shore, most tourism dollars are spent by residents of the region who travel to enjoy the scenery, the natural amenities of the region, and opportunities for outdoor family recreation (Knopp and Blank, 1983).

State economic development plans for the region typically identify tourism as an area to be promoted by investments in recreation facilities, especially marinas, and through state assistance in tourism marketing (Dietzel and Smith, 1983). Also important are decisions concerning public recreation facilities, including parks and other public lands, which comprise 20 percent of the Great Lakes U.S. shoreline and 16 percent of the basin's U.S. area. They are important components of the region's tourism infrastructure (Great Lakes Basin Commission, 1975).

CHAPTER 4

DIRECT AND SECONDARY IMPACTS OF GLOBAL CLIMATE CHANGE ON THE GREAT LAKES BASIN

How would these Great Lakes natural and economic resources be affected by climate modification? To answer this question, The Center reviewed other researchers' scenarios of the impact of global climate change on the Great Lakes basin. These scenarios begin with models of the planet's climate and alter the models to show the effects of doubling CO2 concentrations in the atmosphere. The scenarios which form the bulk of this section use the Goddard Institute for Space Studies (GISS) model to demonstrate the effect of doubling CO2 concentrations to twice that of pre-industrial times. Scenarios based on models by the Geophysical Fluid Dynamic Laboratory (GFDL) and Oregon State University (OSU) are also reported where they differ from the GISS projections. Where information based on another model is used to illustrate the perceived range of scenarios, the scenario used is indicated in the text.

The scenarios summarized here are the results of others' research, funded by the EPA and Environment Canada. In some cases, inferences drawn by The Center have been added, based on related impacts described by the researchers.

In these scenarios, the average annual temperature in the Great Lakes states would increase between 0.9 and 1.2°C by 2010 and 4.3 and 4.7°C by 2055 (Linder and Inglis, 1989). Winter temperatures would be about 5°C degrees warmer (GISS 4.2 to 4.7°; GFDL 6 to 7°), and summer temperatures about 3 to 7°C warmer.

Average daily precipitation would increase 0.05 mm to 0.2 mm. The three scenarios vary in their expectations for seasonal precipitation. GFDL, for example, identifies a 0.5 mm per day decline in summer, while the OSU model shows no change and the GISS scenario identifies a 0.4 mm per day summertime increase. Because precipitation over the lakes depends on the heat storage capacity of each lake, rainfall and snowfall in the basin would vary. Lake Superior precipitation may increase up to 18 percent. Lake Michigan-Huron would remain relatively constant, with a change from +2 to -5 percent. Precipitation over Lakes Erie and Ontario would decline 7 percent.

With global warming, the duration of the Lakes' ice cycle would be expected to be about 5 to 12-1/2 weeks shorter for Lake Superior and about 6 to 10 weeks shorter for Lake Erie. Ice cover would begin to decline significantly between 2011 and 2040, but ice would still form in mid-lake areas some winters (Assel, Volume A). Mean winter snowfall would decrease 20-80 percent, with the greatest change north of the lower Great Lakes. The length of the snow cover season is expected to decrease by 2 to 10 weeks (The DPA Group Inc. 1986). On the Superior basin, the average snow-pack storage would be reduced by more than half; on other basins to the south, the snowpack would be almost entirely absent, resulting in reduced moisture storage in soil and groundwater (Croley and Hartmann, Volume A).

Declines in runoff would range from 1.7 percent over the Superior basin to -42.5 percent over the St. Clair basin. Runoff peaks slightly earlier under the 2XCO2 climate. Lake evaporation would increase from 97 to 221 mm/yr, which exceeds the drop in projected runoff to all the Great Lakes (Croley and Hartmann, Volume A).

As a result of these changes, water levels in the Great Lakes and stream flows through the connecting channels would decline. The scenario based on the GISS model projects a decline in levels of Lake Superior by 0.4 meters, of Lakes Michigan and Huron by 1.3 meters, and of Lake Erie by 1.1 meters. The GFDL model scenario projects larger declines, with reductions in Lakes' Michigan and Huron of up to 2.5 meters, and Lake Erie of 1.9 meters. Projections based on the OSU model show lake level declines of 0.5 meters in Lake Superior, 1.0 meters in Lakes Michigan and Huron, and 0.8 meters in Lake Erie.

These changes would degrade Great Lakes water quality. Eutrophication would be enhanced by the increase in temperature. Oxygen levels in the warmer lakes would decline, especially in the Lakes' depths where the period of thermal stratification may be extended. The annual turnover in the Lakes' waters might not occur, adding to the depletion of oxygen in deep waters. Lower water volumes would increase concentrations of both nutrients and toxic chemicals, further compromising water quality. Water quality deterioration would be greatest in west and central Lake Erie and other shallow basins where oxygen depletion may be exacerbated (The DPA Group Inc., 1986). The nonpoint discharge of nutrients and toxic chemicals may increase with runoff from new farming and urban expansion in the northern latitudes carrying fertilizers and pesticides, and dredging to restore depths in navigation channels resuspending contaminated sediments. Aerial deposition of pollutants may also increase if fossil fuels are burned to meet rising power demands.

Surprisingly, fisheries may benefit because the warmer waters would increase overall biological productivity. A large increase in thermal habitat for coldwater fish would be likely unless the basin was too shallow to contain cold oxygenated water in the summer (e.g., central and western Lake Erie). For most regions and most fishes, habitat and productivity would increase. Increases in warmwater habitats would favor range extensions of native and exotic warmwater fishes. Surprises involving loss of important stocks as well as surprises from intensified species interactions are expected from new and exotic species. Brook trout would decline with the increasing water temperatures and declining flows in streams. Where ice cover is not present, whitefish and other cold- water fish like lake trout may decline. The loss of the ice cover may also reduce the abundance of microorganisms adapted to the protection of winter ice, affecting the fish which prey on them. (Magnuson and Regier, Volume E; Assel, Volume A).

The lower lake levels would also expose new shoreline areas and expand beaches. Over 65 percent of U.S. Great Lakes wetlands could be affected by the lower lake levels. While the wider beaches may reduce shoreline erosion in some places, in others the loss of ice cover which protects shorelines from high-energy winter storms might increase shoreline retreat (Manny, 1984; Croley and Hartmann, Volume A; Assel, Volume A).

Forests and farmlands would also be modified. Tree growth would decline because of lost soil moisture. Under dry soil conditions, forests may change from commercially valuable northern hardwood-oak forests to less valuable oak forests with red maple. Forests may be converted to open woodlands, savannas, or grasslands with small scattered trees on drier sites. A significant change in forests may become apparent in 30 to 60 years (Botkin, Volume D)[2].

Agriculture would also be affected by the projected average 4-6 degree growing season temperature increase and a slight increase in precipitation. Crop yields could increase in the north (e.g., Duluth) owing to warmer conditions and a longer frost-free growing season. In the southern Great Lakes region, however, plants' yield may fall since the increase in temperature causes a decrease in the duration of crop growth cycle. New crops varieties could be required to adapt to these changes. In the southern Great Lake states alternative crops, such as cotton which continues its growing cycle through the whole season, may be considered. Growing two crops within one season may be possible on good soils (Rosenzweig, Volume C; Ritchie et al., Volume C). The need for irrigation is uncertain. Scenarios based on the GFDL model project that water requirements would increase about 90 percent, while those based on the GISS model project a decrease averaging about 30 percent. Where the use of irrigation and chemical fertilizers expands, demands on aquifers and streams will increase. In the north, drainage projects and deforestation to add new cropland would also affect ground and surface water (Rosenzweig, Volume C; Ritchie et al., Volume C).

Overall, a 1 to 2 percent increase in agricultural acreage in the Great Lakes and Corn Belt states is projected, compared to a projected decline in farm acreage in Appalachia, the Mississippi Delta, and southern

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[2] Some authorities have speculated that an increase in CO2 will increase total forest productivity because increasing CO2 increases growth rate of individual trees. But recent studies suggest that the effects of climatic change are very strong. Based on past modeling experience, the climatic effects would more than compensate for any CO2 enhancement effect (Botkin, Volume D).

Great Plains. This northward shift in agricultural production is due to relative advantages of the Great Lakes basin in crop yields and water demand (Adams and McCarl, Volume C).

Other economic sectors would also be affected by climate change. Rising temperatures would increase annual energy use and generating capacity requirements for utilities serving southern portions of the basin where air conditioning and other summer seasonal loads are relatively high. Meeting this new demand with present technology would require an increase of 0.7 gigawatts (GW) to 6.3 GW in generating capacity by 2010, an increase of up to 8.4 percent, with cumulative capital costs estimated between $1.3 and $4.2 billion. New capacity requirements by 2055 would be 11.5 percent to 14.2 percent higher than the increase anticipated without climate change. Most of this increase would occur in peaking capacity. The increased annual cost of constructing and operating the additional generating capacity is estimated at $5-10 billion. New technology, such as superconductivity, or changes in costs of power purchases from outside the region could reduce the amount and cost of new generation capacity required. At the same time, lower lake levels will reduce generation from inexpensive and nonpolluting hydropower. A switch to alternative power sources, such as fossil fuel or nuclear power facilities, would consume additional lake water for cooling, lowering lake levels still further. If the demand for use of coal in power plants increases, demands on shipping will grow. Power production costs would reflect rising costs of navigation (The DPA Group Inc., 1986; Croley and Hartmann, Volume A; Linder and Inglis, Volume H).

Navigation, another important sector of the economy, would be harmed by lower lake levels. Average navigation costs could increase by 5 to 15 or even 30 percent owing to lower vessel loads, traffic backups at the Welland Canal and Sault St. Marie, and the high cost of dredging harbor and channel sediments contaminated with toxic chemicals. For example, a 1.5-foot water level reduction in Lake Superior would decrease cargo capacity by 5 percent, increase transportation costs by 6 percent, and require an additional 16 days to transport cargo. In Lake Erie a 3.2-foot drop in lake level would decrease cargo capacity by 14 percent, increase transportation costs by 14 percent, and require 50 additional days to transport cargo. The variability in annual navigation costs could increase dramatically because of the changes in lake levels. As a result of lower water levels, the trend toward larger, more cost-effective vessels would stop. Increased shipping costs will directly affect industries that depend on Great Lakes navigation to transport their products. Reduced ice cover and a longer shipping season may partially offset some of these effects. An 11-month shipping season may be possible on lower lakes, and a 10-month shipping season may be possible on Lake Superior. Because shippers could take advantage of the longer navigation season to spread their shipments more evenly throughout the year, the overall capacity of the navigation system to move cargo may not decline (Keith et al., Volume H; Marchand et al., 1988).

Climate change would also alter tourism along the Lakes. The longer summer season would offer greater opportunities for camping and park use. However, the decline in water levels and stream flows and reduced water quality could harm water-related recreation, compromising fishing, water skiing, and other activities in shallow Great Lakes' bays and basins, and in tributaries to the Lakes. Maintenance problems in marinas and recreational boating channels will increase. Where sediments are contaminated, marinas will face very high costs for dredging and spoils disposal. Property values of cottages along rivers and lakes could decline with reductions in water levels or water quality. The shorter winter will harm winter recreation. For example, decreased snow and ice cover will hurt the ski industry and ice fishing around the Lakes. (The DPA Group Inc., 1986; Croley and Hartmann, Volume A).

Many observers saw potential foretastes of climate change's effects in the impact of 1988's drought and record heat. By July 1988, hot, dry weather throughout the Great Lakes basin reduced Great Lakes' levels by 0.5 to 0.7 meters from their record highs in 1986. Stream flows in the St. Lawrence River and Great Lakes tributaries declined dramatically. Municipal water demand nearly doubled in the hot weather, and some smaller communities were forced to develop additional water supplies, frequently using Great Lakes water to replace depleted streams, reservoirs, or aquifers. Declining stream flows and increasing water temperatures made compliance with water quality standards difficult, forcing cutbacks in production at a few factories and power plants. Trout and salmon fisheries suffered from the effects of high temperatures and low flows in spawning streams. Waterfowl reproduction fell in parched wetlands.

Agricultural production in the region plummeted, as spring plantings withered in the heat. Electric power demands set new records in response to heavy use of air conditioners. Declines in stream flows reduced hydroelectric production in Quebec, Ontario, and New York by 5 to 15 percent. Great Lakes shippers were forced to lighten their loads by 4000 tons per trip in response to lower lake levels, reducing the efficiency of large freighters by almost 7 percent. While record low levels in the Mississippi River resulted in the rerouting of some U.S. cargoes through Great Lakes ports, Canadian grain exports plunged with declining farm output on the prairies. Tourism at some Great Lakes beaches fell as recreationists stayed indoors out of the heat. Marina owners scrambled to dredge boat slips and launching ramps to maintain depths adequate for recreational boaters (Center for the Great Lakes, 1988; Anon., 1988).

CHAPTER 5

THE IMPLICATIONS OF CLIMATE CHANGE FOR GREAT LAKES POLICIES AND INSTITUTIONS

These changes in the Great Lakes' environment and economy would require modifications in the management of water and land resources and the region's economy. These policy alterations would be difficult for existing institutions to develop and expensive to implement. Where present institutions are weak, management of climate change may not be successful. While the region's abundant water supplies lend it advantages in adapting to climate modification, careful planning and management will be needed to protect the high quality Lakes' environment with which the basin's economy is linked.

WATER SUPPLY

The effects of climate change would increase pressures on water supply management in the Great Lakes basin. Present efforts to improve water supply management in the basin can offer a framework for managing climate change impacts on the Lakes' water supplies, but only if the commitment to coordinated basin management is implemented.

At a fundamental level, climate change would require alteration of the lake level regulations at Lake Superior and Lake Ontario. The need for these changes is recognized in the Great Lakes Environmental Research Laboratory's study of climate change impacts on lake levels, which found that present regulations would not maintain flows in the St. Mary's and St. Lawrence River (Croley and Hartman, Volume A). Modification of these levels could be undertaken by the IJC and the two federal governments. Alterations might be limited to variation in the present lake level control regime, or could require modification of existing physical controls at the two Lakes' outlets. The absence of contemporary concerns, such as environmental protection, from the priorities of the Boundary Waters Treaty would increase the IJC's difficulty in adopting new regulations that balanced the needs of downstream water users, shippers, and shoreline land owners. For example, strict application of the treaty's present priorities in reregulating the outflow from Lake Ontario to the St. Lawrence River might not address the needs for fresh water outflows to protect St. Lawrence River fisheries from the adverse effects of salt water intrusion, or the goals of Lake Ontario recreational marina operators for water depths adequate to maintain their facilities.

The region's new policies on regulating consumptive water use and diversion can be helpful in reacting to climate change, especially if the states and provinces continue to increase public control of large water appropriations. As climate change makes water scarcer, the move away from riparian rights and towards a system of appropriation in managing the basin's water supplies is likely to grow. Parallel development of groundwater law will also be required if irrigation demands increase or aquifers are depleted. Otherwise groundwater users will increase diversions from the Lakes' and other surface supplies to relieve overdrafted aquifers.

Development of the coordinated basin-wide water management program called for in the Great Lakes Charter would provide a framework for the Great Lakes states and provinces to make decisions about reallocation of water supplies reduced by climate change. These reductions in supplies, coupled with increases in consumptive use and growth in Canada's relative proportion of Great Lakes water use, may increase conflicts over water allocation. Coordination of the states' and provinces' systems for regulating water appropriations along the path described in the Charter could help prepare for this increased competition for water supplies. Stronger regional institutions with state and provincial representation will be needed to manage this program. The Charter's basinwide management program, coupled with the IJC's ability to review and condition water diversions from the basin, can provide a framework for water allocation decisions. If both federal governments consent, the IJC could exercise its authority to review diversions to implement the states' and provinces' water management program, providing for shared state-provincial-federal decisionmaking about Great Lakes basin water supplies.

If the states and provinces are not able to develop an effective management program endorsed by the federal governments, water allocation decisions affected by climate change will be less predictable and are less likely to reflect interests of the region. Policies and institutions for allocating water between jurisdictions within the basin, or between the basin and out of basin users, would come under stress. Pressures could grow for out of basin diversions, such as an increase in the Chicago diversion to relieve low flows in the Mississippi River. A long period of negotiation through the IJC, or for Lake Michigan diversions, litigation among Canada, the states and other interests in U.S. federal courts, could be required to resolve these disputes. In the U.S., the lack of a well-described national water policy and the case by case application of the rule of equitable apportionment offer little guidance about how these issues might be resolved by the courts. Federal court adjudication of competing state claims to Great Lakes waters would need to consider climate change impacts to avoid overestimates of the supply available. Efforts to bar water exports of Great Lakes water needed for commerce in other regions may be struck down. Where these water reallocation issues affected navigation, such as barge transportation on the Mississippi River, the Congress might be able to impose a settlement. Decisions made in these international or federal forums may not reflect regional interests as fully as would those made by state and provincial officials.

Water use in the basin is relatively efficient in comparison to other areas in North America. Present policies encouraging additional conservation efforts can enhance this advantage. The demands of increased population, rising power production, and declining groundwater levels could increase water consumption from the Lakes beyond the level presently anticipated. Policies encouraging water conservation could be used to reduce the substantial expenditures required to develop water supply systems to accommodate this growth and to reconstruct existing systems ill suited to lower lake levels. Pressure on water supplies could also be dampened by land use planning or economic management which discouraged expansion of water using industries or land use patterns. For example, power generation by fossil-fueled power plants consumes less water than generation of an equivalent amount of power by nuclear plants. Policies or public institutions capable of guiding these decisions have not been developed in the Great Lakes basin.

One incident in 1988's drought demonstrated the kinds of conflicts about Great Lakes water which might occur with climate change. When falling Mississippi River flows crippled barge navigation there, Illinois proposed that the federal government permit increases in the Chicago diversion from Lake Michigan to the river to enhance navigation. Canada, governors of other Great Lakes states, provincial premiers, and U.S. Senators from many Great Lakes states opposed the diversion, as did Great Lakes shipping and power interests. Senators from Illinois and southern states supported the proposal, asking the Corps of Engineers to invoke "emergency powers" to authorize the diversion based on the federal interest in navigation. The issue was not referred to the IJC for consideration. After several weeks of study, the Corps rejected the proposal, finding it would be ineffective in aiding Mississippi River barge traffic. The acrimony raised by the proposal spilled over into debates about trade relations between Canada and the U.S., hampering agreement on a major tariff reduction agreement.

WATER QUALITY

If the climate change scenarios for the region do occur, water quality management in the basin would be more difficult. Present water quality goals could need revision. If greater anticipatory functions can be developed, present institutions may be capable of managing point source discharges under climate change conditions. Expansion in the proportion of land in farm use could increase the runoff of sediments and pesticides.

The Great Lakes Water Quality Agreement's basic goals of maintaining oligotrophic conditions in the upper lakes and preventing nuisance algae blooms in the lower lakes would become much more difficult to achieve if climate change occurs as projected. The concept of load management for nutrients and elimination of toxic substances would remain valid under climate change conditions. But rising water temperatures, declining water levels, and resulting increases in nutrient and toxic chemical concentrations may require tightening of discharge standards if the agreement's present goals were to be retained. The northward shift in population and agriculture could also influence the agreement, posing additional difficulties in meeting present goals for Lakes Superior and Huron, whose watersheds are now largely undeveloped. Population growth and farm expansion in Canada could increase its need to discharge wastewater to the Lakes, requiring a further reduction in U.S. nutrient discharges if present targets for phosphorous loading are retained. Accommodating these changes could require renegotiation of the water quality agreement.

Implementation of a more restrictive water quality agreement would challenge the region. The new and improved treatment works required to produce cleaner effluent would be expensive. Those seeking water quality improvements would need to compete for limited funds in an era where a host of economic, environmental, and social changes made demands on the region's financial base. Federal clean water legislation or close regional cooperation would be needed to assure that new standards are applied uniformly across the basin, limiting states' and provinces' "shopping" for new industries by lowering water quality protection. Cleanup progress of persistently polluted Areas of Concern would become particularly important, as toxics and other pollutants would grow increasingly concentrated in these areas' shallower waters.

A variety of institutions, such as environmental agencies in federal, state, and provincial governments, and regional or local water quality agencies, have the authority and jurisdiction to develop or implement the policy modifications required. But past practice suggests that policy development is more likely to react to climate change than to anticipate it. The lack of confidence in present forecasts of how and when climate change will affect the Lakes limits the attention paid to climate change effects in water quality policy development. Unanticipated ecosystem reactions to climate change, such as increases in blue-green algae populations, could substantially degrade the Great Lakes' water quality. The inability to anticipate these effects increases the difficulty of considering climate change in water quality planning.

Other aspects of water quality management affected by climate change are not well addressed by the present policy and institutional framework. Increases in nonpoint source pollution due to land clearing and increases in fertilizer and pesticide runoff from expanding agriculture would increase pressure on presently weak policies and institutions charged with nonpoint discharge control. Losses of wetlands could exacerbate these impacts. Pressures on groundwater could also grow if declining surface water quality limits the use of lakes and rivers for water supply or waste disposal. Groundwater quality management policies and institutions at all levels of government are weak in the region. Water quality threats from airborne contaminants could also increase with agricultural expansion or if power demands are met by burning fossil fuels. This is another area where policies and institutions are weak at all levels of government. New policies and strengthened implementing institutions would be required to protect water quality from these threats.

LAND USE

Throughout the basin, declining lake levels would expose lake bottoms and modify shorelines. Who would own lake bottoms exposed by declining water levels is not clear. All the states have long developed doctrines of public trust and agencies charged with controlling State-owned lake bottoms, but a significant increase in their capabilities would be required to protect the public interest in newly exposed shorelands.

Lakefront development in urban areas, such as parks, marinas, and other infrastructure, could require modification or reconstruction to accommodate the new shoreline configuration. While the region's municipalities have generally well-developed land use planning practices and strong planning agencies available to manage the use of this shoreland, the expense of reconstructing shoreline facilities could be considerable. Managing shorelands in rural areas where land use planning institutions are weak would also be difficult. For example, the increasing development of the basin's rural shorelines and the absence of comprehensive shoreline hazard management, even in states with coastal zone programs, are likely to result in high losses if erosion increases on ice-free lakes. Along U.S. shorelines, the Great Lakes exclusion from the coastal barrier program and the preference for structural solutions to shoreline erosion will increase potential losses both from damage to erosion-prone developments and from sunk costs if erosion control structures are no longer needed to protect reconfigured shorelines.

Pressures on public land managers would grow. Foresters would need to seek tree crops suitable for the modified climate. Because of the long lead time required to produce tree crops, these changes may be among the first regional policy decisions which need to consider the prospects for climate modification. Public lands such as national parks and forests could be called upon to provide areas to mitigate the impacts of land use changes on surrounding private lands. For example, public forest lands could be managed to protect native vegetation and wildlife otherwise threatened by habitat loss from forest-type conversions. Recreational use of public lands could also increase with growing immigration to presently rural northern portions of the region, further reducing opportunities for resource production. Present forest planning activities can help in managing these changes.

The long tradition of local control of Great Lakes land use decisions could frustrate planning for climate change. Where climate influenced features like aquifers or shorelines cross jurisdictional boundaries, policy coordination will be difficult if new institutions are not created. Accommodation of larger-than-local concerns, such as powerplant siting, could also be difficult. Relatively well-developed urban land use institutions would be better able to manage the impacts of climate change than their rural counterparts, where climate change impacts may be particularly important. If warmer temperatures make northern latitudes more attractive, immigration may substantially increase populations in the northland's many small cities and villages. Accommodating this population growth would require major changes in present land use practices in these communities and a substantial investment in their infrastructure. In addition, increased agricultural opportunities in the north could put a premium on protection of presently marginal northern farms and of forests where soils are potentially prime. Presently weak rural land use planning institutions are ill prepared to deal with these impacts.

ECONOMIC DEVELOPMENT

The impact of climate change on the region's economic development strategies is mixed. Over the long run, the basin may have advantages in accommodating climate change when compared to other regions of North America. But the economic costs of accommodating those changes would be high, especially if the environment which supports the Great Lakes' economy degrades. The basin presently lacks institutions capable of guiding economic development so that it can best manage climate change impacts.

Demographic changes accompanying climate change might result in immigration to the region. The population base sustaining service industries would expand. Talent and entrepreneurship that has been drained by outmigration from parts of the region could be restored. In some areas, population growth could result in better utilization of existing municipal infrastructure, but only with adequate maintenance in the mean time. In other places, expensive new water supply, wastewater, electrical, and other service systems would be required.

Several key economic sectors seem especially sensitive to climate change. For example, industries which used water for industrial processing or waste disposal would come under pressure. Efficiency in water use and waste disposal would be rewarded. Water-intensive industries traditionally important in the region, such as pulp and paper, could become liabilities. So might industries affected by new restrictions on wastewater discharge to the Lakes. Research and development activities targeted at increasing the water use efficiency of key industries could be very important. Present institutions like the University of Michigan's Industrial Technology Institute could be models for similar research and development efforts which assist key industries in adjusting to climate change. Tax and regulatory structures which reward efficiency would also be helpful.

Electric power generation would be influenced by loss of hydropower capacity, declines in cooling water supplies, and pressures to limit emissions of greenhouse gases. National energy policies intended to control greenhouse gas emissions would strongly affect the region. If policies favor use of nuclear generators to meet growing energy needs, demands on water supplies would increase because of nuclear plants' higher level of water consumption. Demands for nuclear waste disposal would increase. On the other hand, policies which continued reliance on fossil fuels for power generation could increase atmospheric deposition of pollutants in the Lakes and the demands on the Lakes' navigation system.

Under either of these scenarios, power plant development adjacent to the Great Lakes could become especially advantageous if comparatively more severe limits on cooling water supply in other regions prevented power plant siting there. Undeveloped portions of the Lakes' shoreline might be considered for consolidated power generation to serve distant power users, in much the same way that Great Basin power plants now serve power users in southern California. These impacts would be difficult to manage if the present absence of federal and state energy planning continues. Energy policies which encouraged conservation and efficient use of energy could help minimize these potential adverse effects.

An alternative is to meet these demands with production outside the region. Increasing temperatures in neighboring areas will also require additional capacity to meet increases in peak and annual demands. To the extent that this capacity is not utilized fully in these regions, additional power could be available for sale to the Great Lakes states. Power imports to the region could increase, decreasing the region's electric energy self-reliance.

Rural economies based on forestry and agriculture would be transformed by the modification of farm and timber resources. In areas like northern Wisconsin, agriculture could displace forestry, requiring new facilities and technologies for product processing, changes in employment patterns, and other alterations. Farther south, irrigation agencies and facilities to process new crops could be needed. The uncertainty about the timing and impacts of climate change will increase risks associated with long-term investments, such as tree plantations and irrigation works. Financing for these kind of long-term adaptations to climate change may be difficult to obtain. Traditional programs, like government loans and price supports, which subsidize timber and farm economies' might help finance these projects, but their cost could not be anticipated. Educational and research institutions such as agriculture extension and cooperative forestry research programs would be particularly important in transferring technology which assisted in adapting to climate change.

Declining lake levels would clearly strain navigation on the Lakes. Water level reductions of the magnitude forecast would make the Lakes' present navigation system difficult for the existing fleet to use. Costs of transporting bulk products like ore, stone, fuel, and grain would increase substantially, increasing expenses for steel producers, grain farmers in the Canadian prairies, coal-fired power generators, and others who depend on the Lakes' navigation system. At the same time, demands on U.S. ports in the system could increase if low water makes the Mississippi River barge system less reliable. Deepening of navigation facilities would be difficult because of the high cost and environmental effects of dredging. The slow pace of modernization in the Lakes' navigation system over the past three decades suggests that present institutions are unlikely to develop a timely response to these climate change impacts. As a result, demands on the region's surface transportation system could increase. Performance of the region's highway system could be improved by snow free winters, reducing winter maintenance costs.

Tourism would also be altered. Waterfront attractions in urban areas could be harmed by declining water quality and lower lake levels. In rural areas like Minnesota, changes in the fishery and a loss of scenic quality due to lower lake levels and changing forests could hurt traditional tourist activities. Declining lake levels could require expensive alterations to marinas, fish hatcheries, and other public investments that support the present tourism industry. Winter sports, like skiing and snowmobiling, which now help sustain year-round tourism in the basin, would decline. On the other hand, a warmer, longer summer season may offer the potential for a more attractive tourism resource.

Canada, sustained by its comparatively large water supply and buoyed by the general northward shift in agriculture and forestry, might be better able to adapt to climate change than the U.S. This may alter traditional trade relationships between the United States and Canada. The terms of trade across the border could strongly influence the region's response to climate change. Free trade in power, farm and timber products, and other goods would increase the flexibility available in the region to accommodate climate change impacts.

CHAPTER 6

ANALYSIS AND RECOMMENDATIONS

Several themes emerged during the course of the study that warrant examination.

First, additional research is needed to assist policy makers in understanding the impacts of climate change in the region. Better information to verify regional climate models and predict the magnitude and timing of climate effects in the basin is needed. The management decisions confronting regional and local policy makers cannot be made without more reliable forecasts of the magnitude and timing of climate changes. Climate monitoring is necessary to confirm the predictions of climate change models. Since these phenomena occur on a larger than regional (indeed a global) scale, the federal governments together with international organizations should take responsibility for additional work in this area. Additional research on past climate perturbations, like droughts or high lake levels, would assist in understanding potential impacts of climate change in the basin. The responsible agencies should also be charged with providing information that explains climate change phenomena to regional and local decision makers.

For those making decisions within the region now, climate change can be an additional factor which encourages newly developing management trends within the region. Present efforts to improve the Great Lakes' water quality and better manage their water supplies may provide an important competitive advantage in an era when abundant, high-quality water for industry, population growth, and agriculture is constrained elsewhere. In addition, economic development strategies which have promoted research and development, technology transfer, and increased efficiency in preparing for the economic changes of the next decade can help accommodate new challenges which may accompany climate modification. The need to accommodate prospective climate modification is just one more reason to husband water resources, manage shorelines wisely, and provide adequate maintenance for infrastructure. For the time being, new regional and local policies which react to climate change are not needed. Development of these policies will need to await more reliable forecasts of the magnitude and timing of climate changes.

Features which provide flexibility within our region will be especially useful in accommodating climate change. Public lands, aquifer recharge areas, prime farm lands, natural shorelines, and roads, for example, become increasingly valuable, while inflexible infrastructure, such as our navigation system, is less useful in adapting to climate change. Policies, such as the Great Lakes Water Quality Agreement and the Great Lakes Charter, which promote collaboration and adaptation to new conditions can also be useful. Flexibility in responding to changing climate should be a more important criterion for those investing in new infrastructure or making decisions which may be affected by climate modification. This flexibility can assure the region's ability to maintain the reliable public services which support economic development.

The weakness of long-term economic development and land use planning in the region can limit our ability to respond proactively to climate change. Decisions on fuel sources for power generation, for example, have strong influences both on the rate and extent of greenhouse gas generation as well as our ability to accommodate its impact successfully. Similarly, land use planning to maintain some rural open spaces as reserves for future use could be helpful in adapting to climate change impacts. The region presently lacks institutions capable of making or implementing these long-term planning decisions.

Developing a proactive response to the potential for climate change is hampered by the absence of a constituency advocating climate issues in the region's agenda. The absence of useful information and the temporal distance of prospective impacts makes advocacy of climate issues difficult. The general inertia of public institutions and large organizations further constrains the development of a proactive response to the threat of climate change. In the past, most public decision making by national and state or provincial agencies in the region has been characterized by after the fact reaction rather than proactive management. In the case of climate change, this decision making style will be costly. Local and private decision makers can demonstrate greater flexibility and proactive capacity. Providing more convincing climate change information to local and private decision makers can be a first step in developing proactive strategies to manage it.

Rural areas are especially vulnerable to the impacts of climate modification. Economies dependent on agriculture, forestry, and tourism, coupled with weak planning and environmental management institutions, contribute to this vulnerability. Special attention to strengthening successful rural institutions such as the agricultural extension program and resource conservation districts would be helpful in managing climate change's potential effects in rural areas.

Climate change has a strong potential to influence U.S.-Canadian relations, especially in the Great Lakes basin. The general northward shift in agriculture and forestry, the amelioration of harsh climatic conditions, and Canada's relatively abundant water supplies provide Canada with comparative advantages in adapting to climate change. In addition, impacts of climate change could increase conflict over the shared water resources of the Great Lakes basin. Canada's demands on Great Lakes water resources would increase, requiring adjustment of the two nations' use of the Lakes. International agreements, like the Boundary Waters Treaty, may need to be revised to reflect contemporary priorities to be useful in managing these adaptations to climate changes.

Free trade can increase the flexibility available in the region to respond to these changes by allowing easier adjustments in regional economic patterns, such as the production of power, wood products, and food. But it is not clear that Canada's national interests in economic development would be compatible with potential U.S. desires to secure these resources from Canadian producers. Because of these potentially divergent interests and the importance of U.S.-Canadian relations to the Great Lakes basin, collaborative U.S.-Canadian approaches to climate change are desirable. Cooperative international institutions, such as the IJC, provide a useful forum for that collaboration.

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POLICY IMPLICATIONS OF GLOBAL CLIMATE CHANGE IMPACTS UPON THE TENNESSEE VALLEY AUTHORITY RESERVOIR SYSTEM APALACHICOLA RIVER, ESTUARY, AND BAY AND SOUTH FLORIDA

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The appendices include background material on natural resource trends in the Southeast and key policy issues associated with them (Appendix 1). Detailed cased studies along with complete bibliographic references are included by the TVA (Appendix 2); Apalachicola (Appendix 3); and South Florida (Appendix 4). These appendices may be obtained from the principal investigator, Mark Meo.

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CHAPTER 1

INTRODUCTION

This report addresses the policy implications of potential climate change impacts on three geographic regions in the southeastern United States. Recent reports issued by national and international scientific associations (National Academy of Sciences 1983; Bolin et al. 1986) indicate that a doubling in atmospheric carbon dioxide concentrations is likely to cause a global warming trend between 1.5°C and 4.5°C. Measured increases in CO_2 and other trace gases (such as chlorofluorocarbons, methane, nitrous oxide, and tropospheric ozone) are expected to induce climatic changes different from any experienced in recorded history. Although the magnitude and rate of climate change remain uncertain, the environmental impacts associated with climate change may be severe or large in scale and irreversible.

In an effort to address the range of issues associated with potential climate change impacts and the capacity of institutions to adapt to these impacts, the Science and Public Policy Program at the University of Oklahoma examined the policy dimensions of three case studies in the Southeast: (1) Tennessee Valley Authority Reservoir System; (2) Apalachicola River, Estuary, and Bay; and (3) South Florida. The case study findings are generalized where appropriate for the larger Southeastern region.

OBJECTIVES AND METHODOLOGY

The objectives of the report are to identify the range of policy issues associated with predetermined climate change impacts for each case study site and assess the implications for potential institutional adaptation or impact mitigation. Research on the potential biophysical impacts that climate change might have upon these study sites was conducted independently by other researchers for the U.S. Environmental Protection Agency and was made available to the Science and Public Policy Program. Since water is of central importance to both natural and social systems and received primary emphasis from each of the separate EPA subcontractors focusing on potential climate change impacts on the Southeast, an emphasis on water-dependent uses was maintained for the policy analysis studies.

The methodology consisted of two discrete steps. First, each case study region was described with respect to its institutional setting and use of water resources. Second, the key water policy concerns were reviewed, after which the potential climate change impacts provided by independent researchers (TVA: Miller and Brock Volume A; Apalachicola: Livingston Volume E) were assessed with respect to the institutional setting and the degree to which the institutions have the capacity to respond or adapt to climate change.

Scenarios of climate change impacts were developed by individual subcontractors based upon data from atmospheric General Circulation Models (GCMs), which simulated atmospheric parameters under a doubled concentration of carbon dioxide. Data from GCMs were used to alter a 30-year study period (1951-1980) to estimate altered weather patterns for regional climates. The GCMS used by individual investigators were developed by the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton University, the Goddard Institute of Space Studies (GISS), and Oregon State University (OSU).

It should be noted that GCMs, which are experimental models, exhibit differences in the level of abstraction and detail by which the atmosphere is modeled, air-sea interactions are simulated, and geographic scales used. Consequently, the models and the information they generate are less adequate as a basis for prediction than they are for characterization of hypothetical future environments. In this latter regard, the models were employed by investigators to characterize scenarios of likely climate futures and ask "what if" questions about climate change and the institutional capacity to respond or adapt to potential impacts.

Meo

ORGANIZATION OF THIS REPORT

This report includes summaries of three case studies together with an assessment of research findings that addresses the capacity of institutions to adapt to potential climate change impacts. The Tennessee Valley Authority reservoir system is summarized in Chapter 2; Apalachicola River, Estuary, and Bay in Chapter 3; and South Florida in Chapter 4. Chapter 5 presents a framework for systematic comparison of the case studies and includes recommendations for improving strategic planning based upon case study findings.

CHAPTER 2

POLICY IMPLICATIONS OF POTENTIAL CLIMATE CHANGE IMPACTS ON THE TENNESSEE VALLEY AUTHORITY RESERVOIR SYSTEM

As scientific evidence for a change in global climate increases, concern has grown about the potential environmental impacts that climate change might generate for the United States. As part of a study conducted to assess the policy implications of climate change impacts on the Southeast, this report specifically addresses implications for the Tennessee Valley Authority (TVA) reservoir system. The analysis draws upon an independent impact assessment conducted by the TVA for the U.S. Environmental Protection Agency (EPA), personal interviews with TVA officials, and published literature. Potential climate change scenarios were provided to the TVA subcontractors by the EPA and incorporated into a model used for scheduling releases for the TVA's multipurpose reservoir system.

If the environmental impacts from either of two Goddard Institute of Space Studies (GISS) General Circulation Model scenarios of climate change materialize, the TVA reservoir system may be confronted with substantial challenges to its program capabilities in hydroelectric power, navigation, and flood control. Potential climate change impacts based upon a doubling of atmospheric carbon dioxide also may affect the overall environmental quality of the Tennessee Valley region and would require further collective or joint actions by federal, state, and local programs for effective mitigation. Without more coherent and aggressive efforts directed at integrated initiatives to improve water quality in the region, the potential for continued economic development may be diminished.

If the regional climate influencing the TVA system is characterized by more abundant precipitation and runoff during the wet season (GISS 1 scenario), the TVA system may foster regional economic development from benefits attained through enhanced hydroelectric power production and possibly navigation, improved stream water quality for environmental and industrial uses, and increased recreational uses of the reservoirs and streams. At the same time, more water in the system will necessitate attention to risks from dam spills and potential flooding at vulnerable sites (Chattanooga). Intense rainfall could exacerbate nonpoint source sediment and nutrient loading and further diminish reservoir water quality. In contrast, less runoff into the TVA system (GISS 2 scenario) would augment demand for coal-fired or nuclear power, curtail recreational use of the reservoir system, and further impair overall water quality. Each of these impacts would directly affect TVA operations and alter the basic planning framework for fostering regional economic development.

In view of current water and economic development concerns affecting the TVA region, each of these alternative futures emphasizes a near-term need for the TVA to strengthen its mandated missions and promote increased institutional involvement in regional environmental quality management. With respect to deteriorating levels of ground water quality in the Valley and TVA's concern for improving the level of dissolved oxygen in surface waters, a change in climate as portrayed by the GISS 2 scenario could prompt increasing Valley reliance upon reservoir resources for potable water supplies and erode the ability of receiving waters to accept and dilute industrial and municipal wastewater discharges. With modest growth projected for the region over the next decade, current water quality concerns could be exacerbated by GISS 2 impacts. A loss of the economy's comparative advantages could arise from increased costs for water quality improvements passed along to rate payers, individual polluters, or taxpayers in general.

The policy issues raised by the GISS 1 scenario, while substantial and costly, are not inconsistent with the overall mission, strengths, and past performance of TVA; they are likely to raise only minor obstacles to institutional adjustment and change. A wetter environment for the TVA reservoir system would require TVA to reassess a number of technical options that have been raised or developed in earlier years. These include innovative structural solutions such as the use of "dry" dams to contain floods (Chandler 1984), as well as existing nonstructural remedies such as system wide flood plain management that could be improved upon by states and municipalities with TVA technical assistance (Boggs 1986).

Increased recreational use of reservoirs would complement state economic development strategies and provide a wider base for financing necessary improvements. Since the potential climate change impacts from a wetter environment would fall within the jurisdiction of a good portion of TVA's programmatic strengths, the agency could address the institutional and technical aspects of the impacts in a fairly systematic and independent manner. Improvements in hydropower-related systems could be financed by ratepayers in a straightforward way. Service charges on increased recreational use of TVA reservoirs could be used to offset some of the costs associated with water quantity and quality concerns.

Alternatively, as water resources diminished, the drier GISS 2 scenario would tend to increase institutional tensions and conflicts associated with water allocation criteria, specific impact mitigation and resource management strategies, and formulas for financing needed improvements. For example, reduced water supply would increase demands for public involvement in TVA decisionmaking, including revision of reservoir guide curves, and would intensify the need for improved institutional coordination for water quality concerns (such as ground water quality) that are multijurisdictional in scope. As a result, the policy issues associated with GISS 2 impacts would emphasize those management concerns that affect TVA's primary responsibilities and the tradeoffs among issues that shape its ability to carry out specific missions.

The ability of TVA to adapt or adjust to potential climate change impacts and mitigate them where feasible will be constrained by a variety of institutional factors that shape the agency's ability to carry out its mission. Within the next several decades TVA may alter its mission and organizational structure significantly from what it is today. Indeed, the recent corporate reorganization coupled with the worst drought of the century have placed new internal arrangements under considerable external stresses. Although TVA has proven to be an innovative and resilient organization, the degree to which it can successfully adjust to potential climate change impacts is an open question.

Specific attributes of TVA's institutional composition may provide a useful basis for addressing this question for specific impacts related to water surplus (GISS 1 scenario), water shortages (GISS 2 scenario), and water quality (GISS 1 and 2 scenarios). Divided as it is into power and nonpower entities, TVA commands access to sufficient financial resources and technical expertise to satisfy its mission objectives in power operations, but lacks either a comparable mandate or financial resources in its nonpower program areas.

Despite this division, however, TVA has developed a well-deserved reputation for developing and promoting technological and administrative innovations in nonpower program areas. Wirtz (1976) could not identify any instances when TVA received congressional denials for budgeted project requests.

TVA's geographic jurisdiction is well suited for responding to potential climate change impacts from either GISS scenario. Strategies for implementing more unified basinwide management or conjunctive surface and ground water quality management would be compatible with the geographic scope of TVA's planning purview.

However, a recurrent problem that appears to affect TVA programs is the demand for increased public accountability, especially in power operations. Despite its legislated accountability to the people of the United States through congressional oversight, TVA's unilateral decisionmaking authority has yet to be reversed by Congress, excluding legislative amendment. In recent years, rate increases have not been subject to review by Valley customers, nor are ratepayers fully represented in congressional oversight committees. In order to become more responsive to potential climate change impacts on Valley residents, TVA will have to develop more fully its public accountability mechanisms.

Should more precise climate change forecasts become available, TVA currently is well organized to assess the implications of climate change for each and all of its programs and develop responses. However, two constraints to the timely execution of a coherent or systemwide response lie in TVA's legal mandate and the bureaucratic inertia associated with channeling the climate change message through the system and deciphering what courses of action appear appropriate. The first efforts undertaken by TVA staff to examine the implications of climate change are those conducted by Nielsen et al. (1987) and Miller and Brock (Volume A). Additional studies, motivated most likely by the current drought, will greatly improve the agency's understanding of how to manage water shortages effectively (Brown 1988).

General strategies that TVA might pursue to plan for the potential impacts of climate change include the following:

- Revise the TVA Act to address the issues and implications of climate change for regional multiple use water management and economic development.
- Work more closely with state and regional jurisdictions by promoting development planning activities prescribed in Sections 22 and 23 of the TVA Act.
- Address and mitigate the growing threats to ground and surface water quality degradation through more vigorous implementation of such measures as conjunctive use and uniform basinwide management.
- Revise the TVA's internal budget to accommodate environmental management needs in nonpower programs.
- Seek expanded congressional appropriations to pay for environmental improvements.

At present, the potential for TVA to foster adaptive strategies and institutional initiatives designed to deal with detrimental aspects of climate change is quite promising. In a manner that is consistent with its past tradition of addressing new and evolving problems within its sphere of interest, but which also seeks to accommodate the concerns of Valley stakeholders, the TVA has embarked on a system-wide effort to redefine its organizational priorities, including appropriate economic and environmental roles. Through a series of public workshops and various innovations in internal coordination, the TVA, through collaborative federal-state efforts like Land and Water 201, is likely to recast itself as a more responsive and flexible organization which will be better equipped to address impacts associated with climate change.

If TVA is to accommodate climate change impacts effectively, it will likely require more precise impact projections amenable to scientific agreement in order to begin the process of building awareness throughout TVA programs. Due to the cyclical nature of climate variability, a substantial lead time (a decade or more) will be essential for TVA to discern the influence of climate change, to assess the implications for Valley resources, and to adjust its internal operations where appropriate.

CHAPTER 3

POLICY IMPLICATIONS OF POTENTIAL CLIMATE CHANGE IMPACTS ON THE APALACHICOLA RIVER, ESTUARY, AND BAY

The Apalachicola Bay and Estuary is the gulfward terminus of the Apalachicola-Chattahoochee-Flint (ACF) River system, which drains portions of Alabama, Georgia, and Florida. The ACF River system is managed to enhance water supply, irrigation for agriculture, and maintenance of ecological resources, specifically the Apalachicola Bay and Estuary, navigation, hydropower, flood control, and water-based recreation.

The Apalachicola River, Estuary, and Bay are unique in that they represent a successful combination of land-use planning and resource management of a pristine area rich in natural resources. The Apalachicola River is considered to be one of the last major river systems in this country to remain in a relatively natural state (Livingston 1983). Initiatives such as public acquisition of major tracts of land, by the State of Florida, special estuarine reserve designation through the federal Coastal Zone Management Program, and state-managed growth and development of the Apalachicola area have been instrumental in maintaining this uniqueness.

Combined with its ecological uniqueness, the Apalachicola Bay provides an important economic base for Franklin and adjacent counties. The bay is one of the most productive bays in Florida for seafood production with the bay supporting a significant commercial and sport fish, shrimp, oyster, and crab industry. In 1986, the value of the total dockside catch was over $12.1 million with a six-county regional impact on the economy of over $23.3 million (National Marine Fisheries Service 1988; Prochaska and Mulkey 1983). The bay supplies 90 percent of Florida's oysters and 10 percent of Florida's shrimp (Livingston 1983; Miley 1988). The local people have retained cultural and economic ties with the natural resources of the Apalachicola. This is evidenced by the fact that over 85 percent of the Franklin County population makes their living from the bay (Miley 1988).

Water management of the Apalachicola River drainage basin is characterized by overlapping and sometimes conflicting responsibilities between federal, state, and local agencies (Florida Department of Environmental Regulation 1984). While the U.S. Army Corps of Engineers has consistently managed the Apalachicola River for navigation, the Florida state agencies have managed the system for ecosystems maintenance, thus protecting the economic base of the region. Water management practices of the local Franklin County government have been characterized by heavy reliance on the financial resources and technical expertise of the state, combined with a suspicion toward an increased state regulatory and enforcement presence in the Apalachicola area.

CLIMATE SENSITIVITIES AND POTENTIAL CLIMATE CHANGE IMPACTS

The natural resources of Apalachicola Bay would be highly sensitive to climate change impacts, especially those impacts from sea level rise and the increased occurrence of extreme events, such as hurricanes and droughts. Sea level rise would bring increased salinity regimes in the bay. Droughts causing low flows in the Apalachicola River would result in decreased transport of essential nutrients to the bay and increased salinity levels in the bay (U.S. Army Corps of Engineers 1987). Variations of salinity would result in fluctuations of both oysters and oyster predators such as boring sponges, gastropod mollusks, and crustaceans (Livingston 1983).

In addition, the barrier islands and the Town of Apalachicola would be highly vulnerable to sea level rise. The barrier islands, especially St. George Island, are the keys to productivity of the Apalachicola Estuary. The islands act as a barrier to direct release of the nutrient-laden fresh water entering the bay from the Apalachicola River. The islands are the critical component in determining salinity distribution and water flow in the bay (Livingston 1983). Finally, the islands act as barriers against waves and storm surges. Sea level rise would bring erosion, and ultimately inundation, of the islands and the coastline. Most of the barrier islands and much of the coastline would be inundated with a two-meter rise in sea level (U.S. Geological Survey 1982).

Projected Climate Impacts

Using biophysical data acquired on the Apalachicola Bay over the past 15 years and models provided by Dr. C.F. Hains (Volume A) for projected water budgets for the ACF Basin, Livingston (Volume E) has estimated potential changes in estuarine productivity and dominant (commercially valuable) populations of shellfish and finfish in response to greenhouse gas-induced climate change. Hains' models are based on the GFDL, GISS, and OSU climate change scenario predictions, based upon a doubling of carbon dioxide. Livingston also utilizes data concerning sea level changes in the Apalachicola region from Dr. Richard Park (Volume B).

In all three climate change scenarios, Livingston (Volume E) projects a decrease in river flow and in the quantity of important nutrients carried into the estuary. In addition, all three scenarios predict an increase in mean salinity levels. Livingston concludes that these impacts would cause losses in all major categories of seafood catches, including oysters, white shrimp, blue crabs, and finfish. The oyster population will be particularly vulnerable to increased predation as a result of increased salinity. Pink shrimp would be the only species with a small net gain.

Currently, "the summer high temperatures of the Apalachicola Estuary are close to the upper thermal tolerance limits of most of the dominant (commercially important) species in the system" (Livingston Volume E). If temperature change does occur, changes in the structure and productivity of Apalachicola Bay are likely. These changes would include shifts in population dominance and fisheries potential as well as the possible adaptation and/or substitution by tropical species. Livingston's GFDL projections indicate the greatest impact with an increase of 3 to 5 percent in the mean maximum temperatures of the estuary.

With regard to sea level rise, Livingston (Volume E) notes that a two-meter increase by the year 2100 would result in almost total losses of freshwater and saltwater marshes and losses of over half of the swamps of the Apalachicola Basin. Such losses would result in decreased annual particulate organic carbon levels from 337,385 metric tons in 1987 to 51,955 by 2100.

POLICY IMPLICATIONS OF ADAPTATIONS TO CLIMATE CHANGE

The policy implications of adaptation to potential climate change impacts largely involve tradeoffs among structural and nonstructural alternatives that cover a mix of "no action," "stand and defend," and "strategic retreat" strategies. No-action strategies (or continuing to manage the river, estuary, and bay as they currently are being managed) will result in the potential climate change impacts portrayed by Livingston in his impact assessment of the Apalachicola area. Stand and defend options include structural interventions taken to counter the impacts of climate change. Such actions might include the protection of resources, property, and population settlements of the Apalachicola area through a series of structural modifications. An array of structural responses has been identified for countering the effects of advancing sea level, including "soft" structural responses, such as beach renourishment, and "hard" responses, such as groins, bulkheads, seawalls, levees, breakwaters, and jetties (National Research Council 1987; Sorensen et al. 1984). Nonstructural strategic retreat options encompass measures for adapting to climate change impacts while not directly countering them. Strategic retreat calls for near-term optimization of the existing bay resources as well as planning and guiding a shift in the local economy and population settlements.

INSTITUTIONAL ADAPTATIONS

In adapting to climate change, institutions will likely follow a course of dynamic interaction based on the following factors: the sequence of the impacts, duration, magnitude and pervasiveness of impacts, costs to the local and regional economy from different impacts, and the character of the groups directly and indirectly affected by climate change impacts. For each of the subareas in our study (bay, estuary, and river), these factors will likely motivate institutions to combine elements of the three strategies into a "mixed strategy" for adapting to climate change. This mix of strategies would, in turn, determine which agencies would take the lead in adapting to individual impacts of climate change.

Apalachicola Bay

A mixed strategy for the Apalachicola Bay would include options relating to the barrier islands, the Town of Apalachicola, and commercial, residential, and recreational land uses. While a two-meter rise in sea level would not inundate the Town of Apalachicola, the town would become more vulnerable to storm surges. In an effort to protect the Town of Apalachicola from storm surges, structural improvements, such as beach renourishment, could be made on the barrier islands and on the mainland. Residents of the Town of Apalachicola could be further protected by a series of local and county land-use ordinances that would promote use of land not immediately in danger from sea level rise.

Franklin County would require both technical assistance (from the Army Corps of Engineers and the Department of Natural Resources) and financial assistance (from the State Department of Community Affairs and the legislature) in order to provide for protection against sea level rise to the residents of Apalachicola. Franklin County could make use of its comprehensive land-use planning process to adopt ordinances that would make use of land not in danger from sea level rise. If the ordinances were not implemented satisfactorily, the Department of Community Affairs could provide enforcement and financial powers by once again having the area legally designated as an "Area of Critical State Concern."

The Army Corps of Engineers and the State Department of Natural Resources could take the lead in strategic planning for beach renourishment and for financing and performing the structural modifications to the barrier islands and the mainland. The Corps' strength rests in its financial resources and its in-house technical expertise and experience relating to structural modifications to defend coastlines. However, since the Corps is primarily a reactive agency, the State of Florida would need to play the primary negotiating role as to what structural modifications the Corps would perform and the cofunding schedules. The strength of the Department of Natural Resources lies in its strategic planning program for beach restoration. Under this program, the Department's Division of Beaches and Shores prioritizes beach renourishment projects and assesses the long-term need for additional renourishment (Florida Department of Natural Resources 1988).

Apalachicola Estuary

A mixed strategy for the Apalachicola Estuary would include options relating to the purchased lands in the estuarine preserve, loss of habitat, and new settlement opportunities. Until such time as climate change would bring an increase in estuary temperatures, the oyster catch in the estuary could be maximized through management techniques utilizing the latest oyster culture technology. Sea level rise would bring a loss of the purchased lands in the estuarine reserve, but new lands could be opened up for population settlement opportunities.

Because of its proactive mission of research and education, the Apalachicola Estuarine Research Reserve could play the lead role in coordinating all estuarine research and in obtaining, utilizing, and disseminating technical information on oyster culture to the local oystermen. Increased funding from NOAA would be required for the research reserve to build up its staff and in-house expertise base to perform this role. The Department of Natural Resources could play an important role in performing oyster culture and other fisheries research.

The state land planning agency, the Department of Community Affairs, and the Apalachee Regional Planning Council could play the lead role in planning and managing for new population growth in the area. Through its comprehensive planning process and by again designating Apalachicola as an "Area of Critical State Concern," both state agencies could provide technical expertise and financial help to Franklin County government to provide for new population growth in the area.

Apalachicola River

A mixed strategy for the Apalachicola River would include options relating to navigation and to new industrial and economic opportunities. While climate change-induced decreased river flow could make navigation on the ACF Waterway impractical, structural modifications to the navigation channel could be made by the Corps of Engineers. However, the Corps should utilize more estuarine research findings and environmental values in their decisionmaking criteria relating to the navigation channel and the drainage basin as a whole.

New industrial and economic opportunities to diversify and enhance the economy of the Apalachicola River Basin area could include the introduction of freshwater aquaculture and fish processing industries along the river, as well as active promotion of water-related tourism. The Apalachee Regional Planning Council could play the lead role in promoting appropriate economic development strategies for the area as well as promoting funding from the state. Even though the Regional Planning Council has inadequate financial resources, a small staff, and little in-house technical expertise, they have been adept at leveraging outside technical information relating to economic development opportunities from other state agencies and university research units. They have some success in promoting appropriate economic development, such as aquaculture, along the Apalachicola River. The Regional Planning Council would require the cooperation of county and local governments along the river in order to provide the economic development of strategies to minimize the loss of the economic base of support for the area as well as to identify new paths for labor and regional reinvestment that acknowledge the vagaries of climate change.

IMPLICATIONS FOR AGENCIES WITH APALACHICOLA RIVER BASIN JURISDICTION

A number of organizational responses relating to education, first detection, strategic planning, state assistance, and risk assessment, could be taken in the near term by the agencies involved in the Apalachicola River Basin to prepare adequately for the long term. Such organizational responses would enhance climate change planning and the capacity to utilize climate change plans by the State of Florida, Corps of Engineers, Apalachicola Research Reserve, and the local Franklin County government. These responses are discussed in the following section.

The Apalachicola Estuarine Research Reserve, with its mission of research and education and its excellent geographic location, is the ideal organization to respond to national needs for estuarine climate change research. Research could include first detection of climate change impacts in the Apalachicola River, Estuary, and Bay region and the projected impacts on the associated ecosystems. As the research reserve's legislative mandate, the Coastal Zone Management Act could be revised to reflect the need for national estuarine research reserves to carry out climate change research. An expansion of the Apalachicola Research Reserve's legislative mandate would also need to be coupled with an increase, from NOAA, in the research and staff budgets, in order for the research reserve to coordinate and carry out climate change research.

Organizational responses for the State of Florida could include strategic planning and increased state financial support. First, Florida's Growth Management Act of 1985, which calls for state, county, and municipal comprehensive land-use plans, could be amended to include strategic planning for the impacts of climate change. Franklin County's comprehensive plan could be revised to reflect strategic options for adaptations to climate change impacts. Second, because of the impact that climate change will have on the economy of Franklin County, state agency coordination and strategic planning for economic development of the Apalachicola region would have to continue even if the "Area of Critical State Concern" designation is withdrawn. Third, the State of Florida should increase financial support for the Northwest Florida Water Management District to allow them to play a larger role in the Apalachicola River Basin. Specifically, the Water Management District would require increased financial resources in order to play a role in estimating the effects of climate change on the Apalachicola River drainage basin. This would require a state constitutional amendment to remove the millage cap of one-twentieth of one percent for funding of the water management district. A more appropriate constitutional millage cap would be 1.0, which is the current constitutional limits for the other four water management districts in Florida.

There is also a need for climate change risk assessment to be performed for the ACF River basin. As the coordinator of water management studies in the ACF basin, the Corps of Engineers could respond to this need by incorporating risk assessment into their ongoing "308" basinwide water management planning. Risk analyses could be used by the Federal Emergency Management Agency to help revise their insurance rates for coastal properties.

Finally, both federal and state organizations will need to respond with climate change educational efforts, aimed at water resources managers, natural resource policymakers, and the public. The Northwest Florida Water Management District and the Florida Department of Environmental Regulation could play the lead role in bureaucratic education. The Water Management District could play the lead role in estimating the effects of climate change and disseminating that information to other state agencies. The Florida Department of Environmental Regulations Water Department Division could play the lead role in statewide climate change education. Finally, the Apalachicola National Estuarine Research Reserve could play the lead role in educating the public about the potential impacts of climate change on the estuarine and river system.

CHAPTER 4

POLICY IMPLICATIONS OF POTENTIAL CLIMATE CHANGE IMPACTS ON SOUTH FLORIDA

This case study is one of three conducted as part of an assessment of the policy implications of greenhouse gas-induced climate change on the Southeast. The study is a prospective analysis of policy implications based on sensitivities of the water and coastal resources of South Florida to climate change and sea level rise.

South Florida has considerable merit as a case study for developing analogies for the policy implications of climate change in the southeastern United States. The range of annual and interannual variability of current climate conditions in South Florida encompasses many of the conditions that may be anticipated in other portions of the Southeast as a result of long-term global climate change. South Florida's water resources and natural systems also have a high level of sensitivity to many of the conditions that may result from climate change, including sea level rise. South Florida may be viewed, therefore, as an indicator of how biophysical systems may react to stresses imposed by climate change. Finally, extant climate and biophysical conditions in Florida have stimulated development of a sophisticated water resources management institutional structure that can offer insight into options for adapting current policies and institutions elsewhere in the Southeast to contend with the potential impacts of global climate change. The keystone of this water resources institutional structure is the state water management district system.

South Florida consists of the Lake Okeechobee watershed and the area south and downstream of the lake. This analysis focuses only on the lake and the area south, west, and east of it (see Figure 1). Water resources management in the region is characterized by a complex mix of naturally occurring surface and ground water relationships and an extensive water management infrastructure network of canals, levees, pump stations, and spillways. Major water sources include the surface waters stored in Lake Okeechobee and the Water Conservation areas, and ground water from a number of aquifers including the highly mineralized Hawthorn Aquifer and the high transmissivity, surficial Biscayne Aquifer. Surface water provides about 45 percent of all water consumed within the district, while ground water provides the remainder. Ninety-five percent of public and domestic water is drawn from ground water aquifers (South Florida Water Management District 1985b).

Water use management must contend with rapid growth in demand in several competing sectors, problems of ground water contamination from various land uses, and saltwater encroachment. Agricultural irrigation currently accounts for about 64 percent of consumptive use (South Florida Water Management District 1985b). Water supply needs for potable uses must, therefore, be balanced with agricultural demand, the water needs of ecologically sensitive natural systems, such as the Everglades, as well as drainage, flood control, and navigation requirements. South Florida is also characterized by dramatic climate variability, principally in terms of the temporal and spatial distribution of precipitation.

The institutional setting is likewise complex. While the South Florida Water Management District (SFWMD) has the primary functional role in water resources management, it does so in the context of various formal and informal relationships with several federal and state agencies, including the U.S. Army Corps of Engineers, the National Park Service, the state departments of Environmental Regulation, Community Affairs, and Natural Resources, and a host of county and local governments and regional planning councils.

POTENTIAL CLIMATE CHANGE IMPACTS

General Circulation Model analyses of potential climate change impacts on South Florida suggest the following probable trends: (1) an increase in the rate of sea level rise; (2) an increase in the magnitude and frequency of tropical storms; (3) increased variability in rainfall quantity; and (4) increased evapotranspiration (Pielke et al. 1988; Rhoads et al. 1987). These climate change trends have potential implications for water supply quantity and quality, agriculture, navigation, flood prevention and drainage, coastal storm damage, and

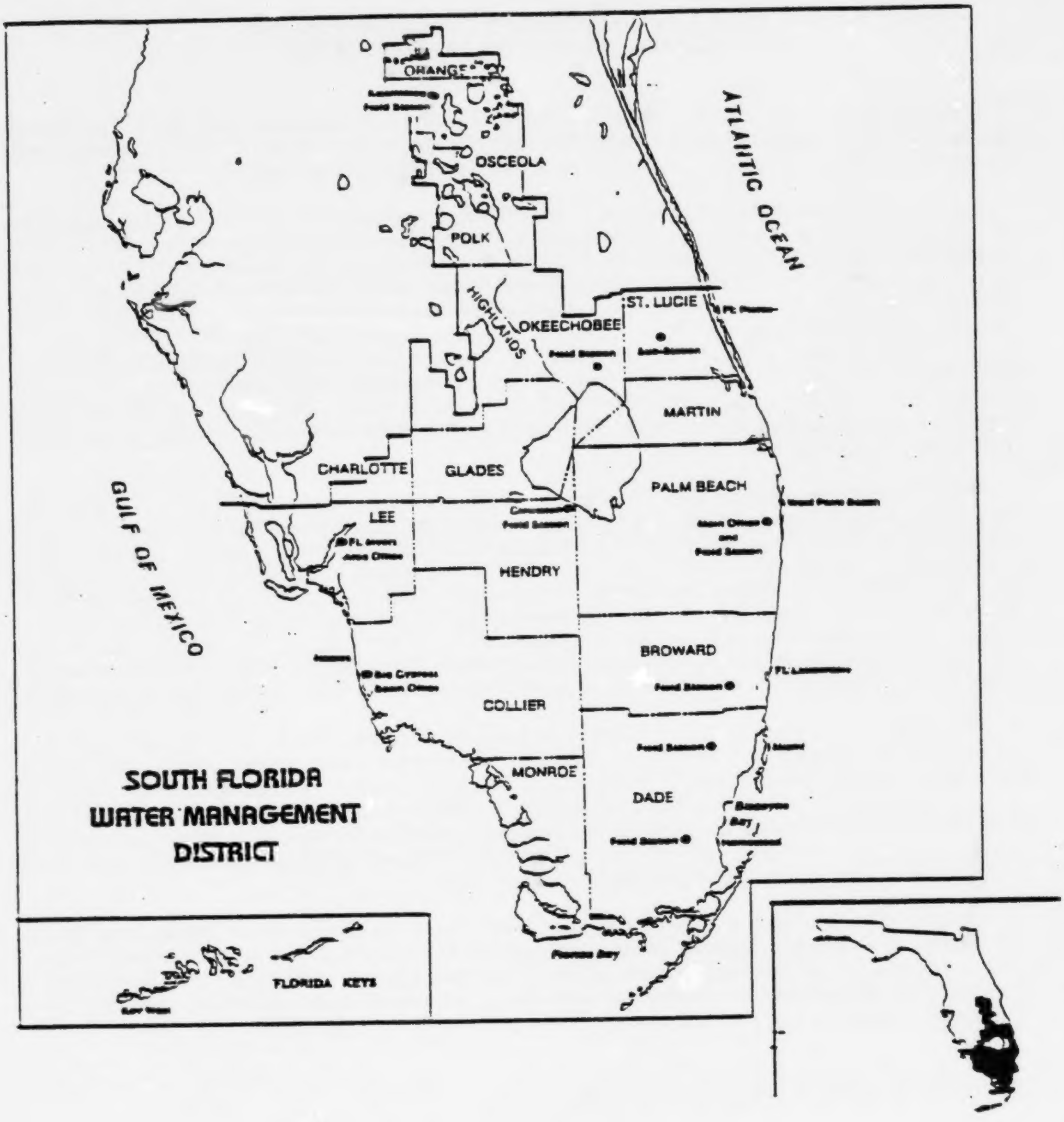
ORANGE
OSCEOLA
POLK
HIGHLANDS
OKEECHOBEE
ST. LUCIE
MARTIN
CHARLOTTE
GLADES
PALM BEACH
LEE
HENDRY
BROWARD
COLLIER
MONROE
DADE
ATLANTIC OCEAN
GULF OF MEXICO
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
FLORIDA KEYS

Figure 1. South Florida Water Management District boundaries.

Source: South Florida Water Management District 1988a.

natural system protection. The sensitivity of each of these resource management concerns was assessed in the context of the following five potential climate change impacts: (1) more frequent short-term droughts or prolonged water shortages; (2) increased wet season precipitation; (3) increased incidence of tropical storms; (4) sea level rise; and (5) tropical pest invasions.

Sea level rise will alter patterns of settlement and land uses and thus will be a major factor in determining both altered demand for potable water and the availability of supplies to meet that demand. Altered land use will affect susceptibility to hurricane damage as will sea level rise-induced changes in erosion rates and storm surge heights.

Sea level rise could pose a major challenge for the existing flooding and drainage system in South Florida which relies principally on gravity-flow (Rhoads et al. 1987). Pumped drainage may be required in a large proportion of the agricultural and urban areas. Sea level rise also is likely to result in higher flood waters upstream (National Research Council 1987), which could exceed the capacity of the perimeter levee along the western edge of the urban coastal ridge. Assessment of these potential impacts presently is constrained by the fact that flood control system design levels are no longer clearly defined due to significant changes in land use that have occurred since the system was designed and constructed (Slyfield 1988).

Progressive coastal saltwater intrusion due to sea level rise may aggravate the necessity of relocating surficial aquifer wellfields or for making diversions of freshwater through canals to maintain sufficient head to retard advance of saline ground water plumes. There are constraints, however, to inland relocation of wellfields in some areas (Baker 1988; Thatcher 1988).

Another potential result of climate change is an increase in tropical storm and hurricane frequency (Emanuel 1987). The urban coastal counties of South Florida plus the Florida Keys will be acutely vulnerable to such climate change impacts in the absence of policy interventions (South Florida Regional Planning Council 1987b). Sea level rise will alter the coastal hurricane damage scenario in terms of what areas are susceptible to major storm impacts. In the absence of intervention, significant areas currently exposed to major storm impacts will be inundated, while inland areas currently not susceptible to storm surge damage will be threatened. To the extent that unmanaged mangrove and beach dune storm buffer systems cannot be established apace with rising sea level, storm exposures are likely to increase. Higher sea levels in shallow water areas typical of the South Florida coast also may result in higher storm surges (National Research Council 1987). Current beach resources will be significantly affected through inundation and possibly as a result of accelerated erosion as well.

Decreased rainfall during the South Florida dry season, coupled with higher temperatures and associated evapotranspiration, could lead to more frequent and severe short-term water shortages. Some of the crops currently grown are relatively tolerant of climate variability, but their sensitivities to short-term water shortages have not been well defined (Coale 1988a). Irrigation demands would be expected to increase under such circumstances, which would further tax water supply capacities. More frequent water shortages or long-term drought also could reduce economic returns from commercial and recreational boat traffic on the Okeechobee Waterway.

Increased annual temperatures could lead to more rapid loss and subsidence of the Everglades muck soils due to biochemical oxidation, and peat fires, which often occur during drought conditions, could become more problematic. The potential for increased invasions of exotic pests from the tropics also poses possible, although ill-defined, impacts for agriculture and public health in South Florida.

Significant increases in wet season rainfall could stress the water storage and pumping capacity of the Central and South Florida Flood Control Project (Rhoads et al. 1987). Inability to remove sufficient water from drained agricultural areas could result in decreased production of some crops. To the extent that the drainage system is capable of or modified to accommodate significant increases in runoff, greater discharges would probably be required to both the Everglades National Park and the major estuaries. Long-term increases in the volumes of freshwater discharged to these ecosystems could alter their biologic composition and ecologic functions.

Dramatic changes in terrestrial and aquatic ecosystems also can be anticipated as a result of sea level rise in areas subject to inundation or altered tidal influence. As much as 45 percent of Everglades National Park could be below sea level by 2030, with an additional 5 percent subject to tidal influence (Rhoads et al. 1987). Sea level rise also will dramatically alter the physical conditions that largely define the shallow water habitat of Florida Bay (Hendrix 1988). Similar impacts are likely in Biscayne Bay and the Indian River Lagoon. Major natural features, such as the Pennekamp coral reef and the Florida Keys, and numerous rare and endangered species may be at risk from sea level rise impacts as well as habitat alteration engendered by changes in meteorologic conditions.

ADAPTIVE STRATEGIES FOR CLIMATE CHANGE

Strategies for contending with the impacts of greenhouse gas-induced climate change can be divided into two categories: (1) adaptive strategies for projected impacts on specific resources and (2) organizational strategies for enhancing institutional capacity to respond to the projected impacts. Some of the strategies currently employed by the SFWMD and other institutions to contend with water and coastal resources management problems in South Florida will have applications in adapting to climate change impacts.

Current resource management strategies pertinent to climate change adaptation in South Florida include those directed at the following issues: (1) coordination of land use, water quality, and water quantity management; (2) efficient water use; (3) contingency planning for drought management; (4) minimizing storm losses; and (5) protection and enhancement of natural systems. Coordination between land use management and water resources management, and integration of water quality and water quantity management, are critical not only to near-term effective water resources management but also to coping with the additional stresses that may be imposed on water supply quantity and quality as a result of climate change. Recognition of the importance of these issues by the SFWMD was responsible for the local government assistance and coordination initiative embodied in the district's Office of Resource Assistance, the recently begun Water Use Management Planning Program, and state legislative proposals that eventually resulted in the 1987 Surface Water Improvement and Management legislation.

Increased water use efficiency is essential to accommodating projected water supply demands in South Florida. A water use efficiency strategy also is clearly an essential component of any adaptive strategy for contending with climate change in South Florida. The primary strategy being employed by the SFWMD is through the leverage afforded by its water use permitting powers. The Governing Board has taken the position that the use of water for nonpotable purposes from sources acceptable for potable use is "neither reasonable and beneficial nor in the public interest" where economically feasible alternative sources can be developed to meet nonpotable demands (Woodraska 1984). The district also is exploring other strategies such as exempting permittees from water shortage restrictions if they are served by a dual potable/nonpotable water supply system and incorporating inverted rate structure requirements in future public water purveyor permits (Morgan 1988; Rogers 1988).

Drought management strategies are an essential supplement to the water use efficiency strategy. To the extent that greenhouse gas-induced climate change increases the potential for short-term or more prolonged and geographically extensive water shortages, a drought management contingency strategy also is important to climate change adaptation. The SFWMD Water Shortage Plan contains explicit mandatory and voluntary consumptive water use restrictions for different water uses for four levels of water shortage and for a water shortage emergency within specified water source classes. The district also has developed a model local water shortage enforcement ordinance and promoted its adoption.

Flood control in agricultural and developed areas is the one area where strategic water resources planning seems to have lagged most recently in South Florida. While both the district and the Corps of Engineers recognize that major changes in land use since design and construction of the Central and South Florida Flood Control system have altered design capacities, sufficient resources have not yet been marshaled for a comprehensive reanalysis of the system. However, a comprehensive review of the system is envisioned within the next few years (Rhoads 1988c). The district is, however, making strategic use of targeted flood and drainage control system analyses. Results are used to assess the adequacy of land use controls for preventing further stress on flood and drainage system capacities and in writing surface water management permits.

Minimizing coastal damage from major storms and hurricanes is principally the province of county emergency management agencies, the State Department of Community Affairs Division of Emergency Management, and the Army Corps of Engineers. A hurricane contingency planning study completed by the South Florida Regional Planning Council in 1987 will serve as the basis for developing federal Section 406 hurricane hazard mitigation plans by local governments.

The strategic concern with natural system protection and enhancement is how to achieve this objective while contending with other water resources management objectives keyed to public health and safety, i.e., flood protection, drainage, and water supply quantity and quality. A similar issue must be confronted in adaptive policies for contending with greenhouse gas-induced climate change, but it is complicated by the potential direct effects of climate change on individual species, natural communities, and ecosystems. There are four major components to the multi-institutional regional strategy for protecting and enhancing natural systems in South Florida: (1) resource impact assessment and mitigation; (2) resource acquisition; (3) resource protection and enhancement through direct management; and (4) resource protection and enhancement through regulation.

These four strategic components should provide a basis for contending with the indirect impacts of climate change on natural systems, i.e., those that result from climate change impacts on use and management of water resources. These strategies will have little utility, however, in dealing with the direct effects of climate change on individual species and ecosystems. Significant management interventions will be necessary to preserve species and communities whose climatological tolerances will be stressed or exceeded by greenhouse gas-induced climate change. In many instances the major policy issue will be whether to attempt to mitigate climate change impacts on natural systems or allow them to adjust to new biophysical equilibria.

In addition to substantive adaptive strategies, opportunities exist for enhancing institutional capacity for contending with both current water resources management concerns and the potential impacts of climate change. These include strategies to increase interagency coordination, alter the organizational design and operation of major water management institutions, and acquire and analyze data needed to detect and assess climate change impacts. Interagency coordination opportunities mainly involve increased coordination between the district and local governments; greater coordination among water supply, drainage, and wastewater treatment service districts at the subregional level; and consensus building.

Two critical dimensions of organizational design and process affect institutional capacity to manage water resources: (1) ability to integrate the expertise and resources of multiple disciplines; and (2) the resources and technical ability to acquire, analyze, and act upon scientific and technical information. Both are important to an institution's ability to define the probable impacts of greenhouse gas-induced climate change, detect those impacts when they occur, and assess and implement adaptive responses. The water management district's major initiatives for enhancing organizational strategic planning and response capabilities have been the institution of formal matrix-style planning and problem-solving and creation of the Office of Resource Assistance as the organization's internal and external boundary spanner (Harvey 1988).

CLIMATE CHANGE POLICY IMPLICATIONS AND OPTIONS

The major policy issues to emerge from persistent seasonal water shortages or the occurrence of prolonged droughts as a result of climate change will involve assessing economic, distributional, and natural resource tradeoffs between structural and nonstructural alternatives for increasing supplies or water use efficiency versus the costs of economic losses from chronic water shortages. The SFWMD's current efforts to increase coordination of land use, water quality, and water quantity management and planning, and their drought management contingency strategies, offer a substantial basis for quantifying and assessing the costs and benefits of alternative adaptive strategies, once better data are developed on the timing and magnitude of climate change impacts. Organizational strategies to increase interagency coordination and consensus building also will be important to implementing adaptation strategies effectively.

The major policy options for significantly increasing water supply storage and distributional capacity include the following: (1) creation of additional storage capacity, either in new shallow reservoirs analogous to the water conservation areas or through deepwell injection into saline aquifers; (2) development of additional wellfields; (3) use of desalinated brackish ground water; and (4) pumped drainage to more effectively recharge lower east coast surficial aquifers (Rhoads et al. 1987; South Florida Water Management District 1982b). Policy options for increased water use efficiency include: (1) water supply backpumping; (2) development of dual potable/nonpotable water supply systems; (3) substitution of drought-resistant landscaping materials and agricultural crops; and (4) institutional mechanisms for promoting the development and use of such systems.

Adaptive strategies pertinent to the maintenance of navigation capabilities along the Okeechobee Waterway will be a function of any shifts in seasonal precipitation that may occur. A decrease in dry season rainfall may require use of backpumping or increasing surface water storage capacity, either in the lake itself or in new shallow-water storage facilities comparable to the current water conservation areas.

Potential increases in hurricane incidence and the rate of sea level rise will significantly affect the tradeoffs to be considered in local government hurricane hazard mitigation strategies. Different areas will be subject to different levels of potential damage. Public land acquisition programs and land development controls will need to be modified. An array of structural responses has been identified for countering the effects of advancing sea level which may be applicable in developed coastal areas. These include "soft" structural responses, such as beach renourishment, and "hard" responses, such as groins, bulkheads, seawalls, revetments, levees, breakwaters, and jetties (National Research Council 1987; Sorensen et al. 1984).

As noted above, wellfield relocation will be necessitated by increased saltwater encroachment due to sea level rise, especially along the lower east coast. This option will be part of the larger mix of policy issues concerning water supply if increased droughts also result from climate change. If shifts in precipitation regimes yield a net increase in rainfall, it may be possible to counter the advance of saltwater intrusion to some extent with increased freshwater storage and maintenance of higher fresh ground water heads through canal recharge. The predominant option for adapting to increased inland drainage and flooding problems due to elevated sea level is likely to be a shift to pumped drainage. The capital and operating costs of such a strategy would be substantial, and the tradeoffs considerable.

The immediate need for contending with the potential for increased tropical pest invasions in South Florida is to conduct more research. Little work has been done to assess how climate change may create conditions for survival and breeding of new pests that may be easily introduced in South Florida through natural and human transport mechanisms.

PROSPECTS FOR ACTION

The water management district's capabilities to acquire, analyze, and act upon water resources and climate change information is substantial. No formal effort has been made, however, to incorporate climate change into the district's planning and decision making (Rhoads 1988b). Key individuals within the organization are cognizant of the implications raised by climate change, but this level of awareness has not penetrated significantly through the agency. The consensus among district personnel who are cognizant of potential climate change impacts is that the uncertain timing, direction, and magnitude of those impacts significantly constrains a concerted initiative at this time. Major initiatives in water resource management in the state and by the district itself typically have occurred in response to perceived crises (DeGrove 1988; Rhoads 1988b). It has been suggested that it will probably take a "well-defined, imminent crisis" to stimulate concerted action directed at contending with climate change as well (Rhoads 1988b).

The U.S. Army Corps of Engineers, whose major presence in South Florida is through the Jacksonville District, is primarily a reactive rather than proactive agency. The Corps' greatest adaptive capacities are in flood control and coastal erosion control. Its involvement in water quality and water supply management in South Florida has been recent and tentative. The Corps' awareness of potential impacts of climate change also appears to be recent and not significantly diffused through the organization at either the district or national levels.

The capacities of county and local governments to manage water resources or to adapt to climate change are far less extensive. Their recognition of the potential impacts of climate change varies from none to very simplified generalizations limited almost exclusively to sea level rise. Most officials acknowledge being aware of the concern, but virtually all profess a lack of significant concern because of the perceived long-term nature of the phenomenon and the greater urgency of other issues.

CHAPTER 5

INSTITUTIONAL CAPACITY TO ADAPT TO CLIMATE CHANGE: COMPARISON OF SOUTHEAST CASE STUDIES

INTRODUCTION

Climate change is likely to alter natural systems in ways about which today's scientists can only speculate. An increase in mean global temperature coupled with altered weather variability might induce numerous and varied environmental changes from the species level through the ecosystem level. In both natural and managed systems, for instance, altered climate could increase summer dryness and subsequently increase risks of fires, pest infestations, or drought events. Strategies designed to address any of the effects of climate change will depend greatly upon the capability of institutions to develop and implement mitigation or adaptation steps that will foster mutually beneficial interactions between society and environment.

This chapter assesses the degree to which public institutions possess the capacity to adapt to potential climate change impacts and identifies specific organizational strengths and weaknesses that pertain to possible climate change impacts in the Southeast. Information developed in each of the case studies (TVA, Apalachicola, and South Florida) is evaluated against a set of criteria which form the basis for assessing institutional capacity to adapt to climate change. The case study information is based upon hypothetical scenarios of future climate change and subsequent impacts that primarily affect hydrologic systems. Accordingly, the comparative analysis emphasizes water resources with further disaggregation into four distinct subcategories: water surplus, water scarcity, water quality, and sea level rise. These findings are then expanded upon to assess the implications of climate change for local, state, and national levels of government with recommendations offered for the Southeast in general.

ASSESSMENT FRAMEWORK

As climate change unfolds, its initial impacts upon the biophysical system are likely to affect climate-sensitive resources which will, in turn, alter the distribution of socioeconomic benefits. Institutions can moderate climate change impacts and the effects they might have upon sensitive social systems. Climate vulnerability can be characterized as the degree to which social uses of specific resources are at risk, or might suffer damages from potential climate change impacts. Therefore, vulnerability, in this sense, is a function of institutional capacity to mediate potential climate change impacts on climate-sensitive natural resources.

The institutions of interest in each of the Southeast case studies comprise a varied array of public agencies at the federal, state, and local governmental levels. The institutional composition in each case study reflects the different criteria that establish the water resources management missions and responsibilities of individual public agencies.

A major institution in the Southeast, the TVA is a federal agency that is unique in its purpose, organization, and role in the Tennessee Valley as well as the United States. As the largest electric power utility in the nation, it has commanded close attention from analysts for many years. However, the absence of comparable organizations has limited the application of policy research findings. Yet, its technological leadership in power production has provided many valuable lessons in energy and environmental policy.

The federal system of governance is well represented in the Apalachicola case study with agency involvement at the local, regional, state, and national levels. The acknowledged importance of the oyster fishery to the local and regional economies has motivated development of an intricate collaborative network of public institutions in northwest Florida directed toward preserving the environmental quality of the river, estuary, and bay areas.

The dominant institutions in the South Florida case study are the South Florida Water Management District, a substate agency, and the U.S. Army Corps of Engineers. In sharp contrast to the Apalachicola case study, the South Florida hydrologic basin lies entirely within the boundaries of the Water Management District, and the region is highly populated with a growing economy. South Florida has also experienced significant environmental alteration and environmental abuse in the past, and is the subject of an extensive natural system restoration effort.

Institutional Attributes

In order to gauge the vulnerability of case study regions to climate change, a set of qualitative scoring criteria was used to rank specific attributes of key organizations in each of the case studies. A composite score for each organization provides an index of overall institutional capacity to adapt to impacts generated by climate change scenarios. In view of data limitations and measurement constraints, the institutional rankings are ordinally scaled. The evaluation methodology was applied consistently with prior agreement on working definitions.

Key institutions in each case study were evaluated for 15 separate attributes, several of which were grouped under common headings. Of primary interest are available financial resources and technical expertise with which agency planning and mitigation options can be formulated and assessed. Since climate change impacts may occur beyond the planning horizon of many agencies, sufficient financial resources are an important factor for the conduct of exploratory or anticipatory studies. Given the scope of potential climate change impacts, access to scientific and technical expertise also is important to identify key issues and resolve uncertainties; to examine implications of potential impacts; and to develop mitigation or adaptation strategies that are technically, socially, and politically feasible.

Four attributes that address feasibility are related to the political, social, and legal factors that define the responsibilities and limits of agency jurisdiction. The statutory authority or political power that is established by legislative action includes federal, state, or local laws that enable an agency to achieve its goals. The geographic range in which agency activities are authorized addresses the ability of an agency to develop plans and manage programs that fall within a region and which allows rational water resources management policies to be implemented effectively. Authority for regulatory enforcement reflects the degree to which compliance with agency goals can be routinely achieved. Public accountability is a measure of the institutional mechanisms established by the agency to educate, coordinate, or communicate with the public about planning, decision making, and management actions taken by the agency that affect the public's overall welfare.

Responsiveness of an agency to mandated actions or short-term forecast climate variability is characterized as either proactive (i.e., taking anticipatory action) or reactive (i.e., taking retroactive or compliance actions). These two attributes distinguish between agencies that employ environmental scanning or promote development of strategic planning capability within their separate policy subsystem or regulatory network and those which do not.

Technical information, which is key to the development of alternative strategies, is characterized by initiatives undertaken to acquire existing or new information and those that are undertaken to act upon acquired information through such activities as forecasting, modeling, and impact assessment. These measures, which are admittedly gross, aggregate independent research activities with managerial or administrative information management and analysis.

Institutional planning capacity is ranked both in relation to how historic climate information is used in investment decisions for long-term planning and the ability of agencies to adapt to climate change as new information becomes available. Organizational coordination is assessed with respect to activities internal to an agency as well as external. Internal coordination refers to operations that are interdepartmental in scope and conduct. External coordination encompasses networking or collaborative arrangements that include other agencies or subgovernments.

Since climate change is a phenomenon that will increasingly command institutional attention and response, awareness of the "greenhouse effect" or the ability of an agency to become aware of the greenhouse effect was included as an important factor for assessing the overall capability of institutions to adapt.

Comparative Assessment of the Case Studies

Rankings of institutional attributes for each of the three case studies are shown in Tables 1-4, which include separate scores for conditions of water surplus, water scarcity, water quality, and sea level rise, where appropriate. Each attribute is ranked along a scale ranging from "Well Developed" (****) to "Not Developed" (*). Where information is insufficient for scoring purposes, a "?" is used.

Institutional Capacity - TVA Reservoir System

Institutional capacity examined in the TVA case study is divided between power and nonpower operations. As discussed in the case study, the TVA can be described as two separate organizations operating under one board of directors. Power operations are underwritten by a separate financing authority and paid for by TVA utility ratepayers. Achieving economic competitiveness with other utilities plays a key role in TVA strategic planning. The recent corporate restructuring was undertaken at the behest of the new Board Chair in order to stabilize utility rates and enhance TVA's ability to attract new customers.

Power operations score very well in financial resources under conditions of water surplus and scarcity as well as for water quality. Expertise scores are high for both power and nonpower operations, except for nonpower activities in times of water shortages.

Of the political/social/legal factors, TVA scores less well with respect to public accountability, an issue that has been controversial for TVA in recent years. For water quality, TVA scores poorly in these attributes. This is a result both of the omission of water quality as an explicit goal in the TVA Act as well as inadequate attention given to the issue by Valley states. Accordingly, TVA scores poorly in institutional responsiveness to water quality issues while attaining high rankings in proactive planning for both water surplus (its original mission) and water shortage (as a result of its leadership role in recent droughts).

In the acquisition and utilization of technical information, TVA scores highest for water surplus and poorest for water quality. In the last four years, TVA has demonstrated its competence in the acquisition and use of information for water shortages, especially the most recent drought.

Reflective of its mandate, TVA has utilized historic climate variability in its planning and investment criteria related to water surplus. Nonpower operations rank more highly than power operations on this attribute for water quality conditions, but both power and nonpower activities score poorly under water shortage conditions.

Institutional Capacity - Apalachicola River, Estuary, and Bay

The overview of institutional capacity to adapt to climate change for the Apalachicola River, Estuary, and Bay focuses on the Florida agencies with primary jurisdiction in the Apalachicola area, the Mobile District of the U.S. Army Corps of Engineers, the Apalachicola Estuarine Research Reserve, and the local Franklin County government. Pertinent climate change impacts include sea level rise and water shortage due to decreased flow in the ACF River basin. Relevant Florida state agencies include the Department of Environmental Regulation, Department of Community Affairs, Department of Natural Resources, Game and Freshwater Fish Commission, and the Northwest Florida Water Management District.

The Florida agencies are well equipped to contend with the possible impacts of greenhouse gas-induced sea level rise and water shortage. The agencies have a history of responding proactively to environmental issues by: (1) protecting the ecosystems of the Apalachicola area through a combination of land acquisition programs

Table 1. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Surplus

	INSTITUTIONAL ATTRIBUTES							
			Political/Social/Legal Factors				Responsiveness	
CASE STUDIES Key Organizations	Financial Resources	Expertise	Statutory Authority/ Political Power	Geographic Jurisdiction	Regulatory Enforcement Authority	Public Accountability	Proactive	Reactive
Tennessee River Basin:								
Tennessee Valley Authority								
Power Operations	****	***	****	****	***	**	****	***
Nonpower Operations	**	***	**	****	***	**	***	****
South Florida:								
U.S. Army Corps of Engineers								
Jacksonville District	***	****	****	****	***	?	**	***
State of Florida								
South Florida Water Management District	****	****	****	****	****	****	***	****
Urban Coastal Counties[a]	***	***/**	***	***	***/**	?	***/**	****/**
Rural Counties[a]	**	**	***	***	***/**	?	?	?

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 1. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Surplus (continued)

CASE STUDIES	INSTITUTIONAL ATTRIBUTES					
	Technical Information		Planning and Investment Criteria Based Upon Historic Climate Variability	Organizational Adaptation Addressed by Current Planning	Organizational Coordination	
Key Organizations	Acquisition	Utilization			Internal	External
Tennessee River Basin:						
Tennessee Valley Authority						
Power Operations	****	****	****	***	****	****
Nonpower Operations	****	***	****	**	***	**
South Florida:						
U.S. Army Corps of Engineers						
Jacksonville District	***	***	***	***	?	?
State of Florida						
South Florida Water Management District	***	****	***	***	****	***
Urban Coastal Counties[a]	****/**	****/**	?	****/**	***/**	***/**
Rural Counties[a]	?	?	?	?	?	?

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 1. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Surplus (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES Organizational Awareness of Potential Climate Change Impacts	INSTITUTIONAL CAPACITY TO ADAPT TO CLIMATE CHANGE
Tennessee River Basin:		
Tennessee Valley Authority		
Power Operations	**	***
Nonpower Operations	**	***
South Florida:		
U.S. Army Corps of Engineers		
Jacksonville District	**	***
State of Florida		
South Florida Water Management District	***	****
Urban Coastal Counties[a]	*	***
Rural Counties[a]	*	?

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 2. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Shortage

INSTITUTIONAL ATTRIBUTES

CASE STUDIES Key Organizations	Financial Resources	Expertise	Political/Social/Legal Factors				Responsiveness	
			Statutory Authority/ Political Power	Geographic Jurisdiction	Regulatory Enforcement Authority	Public Accountability	Proactive	Reactive
Tennessee River Basin:								
Tennessee Valley Authority								
Power Operations	****	***	****	****	?	**	****	***
Nonpower Operations	**	**	****	****	?	***	****	***
Apalachicola Estuary and Bay:								
NOAA/Estuarine Reserve	***	**	***	****	*	***	****	***
U.S. Army Corps of Engineers Mobile District	****	****	***	****	***	****	*	****
State of Florida								
State Agencies	****	****	****	****	****	****	****	****
Apalachicola Local Government	*	*	**	****	*	****	*	**
South Florida:								
U.S. Army Corps of Engineers Jacksonville District	****	***	***	****	***	?	*	***
State of Florida								
South Florida Water Management District	****	****	****	****	***	****	****	****
Urban Coastal Counties[a]	***	***/**	****	***	****/***	?	***/**	****/***
Rural Counties[a]	**	**	****	***	****/**	?	***/**	****/***

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 2. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Shortage (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES Technical Information Acquisition	 Utilization	 Planning and Investment Criteria Based Upon Historic Climate Variability	 Organizational Adaptation Addressed by Current Planning	 Organizational Coordination Internal	 External
Tennessee River Basin:						
Tennessee Valley Authority						
Power Operations	****	***	**	***	****	***
Nonpower Operations	****	***	**	***	****	***
Apalachicola Estuary and Bay:						
NOAA/Estuarine Reserve	****	****	****	***	***	****
U.S. Army Corps of Engineers Mobile District	***	**	****	***	****	***
State of Florida						
State Agencies	****	****	****	****	****	****
Apalachicola Local Government	*	*	*	*	*	*
South Florida:						
U.S. Army Corps of Engineers Jacksonville District	***	***	**	***	?	?
State of Florida						
South Florida Water Management District	****	****	****	****	****	****
Urban Coastal Counties[a]	***/*	***/*	***/*	****/**	***/**	***/**
Rural Counties[a]	?	?	?	?	?	?

(continued)

Rankings:	
Well Developed:	****
	***
	**
Not Developed:	*
Insufficient Information:	?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

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Table 2. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Shortage (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES Organizational Awareness of Potential Climate Change Impacts	INSTITUTIONAL CAPACITY TO ADAPT TO CLIMATE CHANGE
Tennessee River Basin:		
Tennessee Valley Authority		
Power Operations	***	***
Nonpower Operations	***	***
Apalachicola Estuary and Bay:		
NOAA/Estuarine Reserve	****	***
U.S. Army Corps of Engineers Mobile District	***	***
State of Florida		
State Agencies	****	****
Apalachicola Local Government	*	*
South Florida:		
U.S. Army Corps of Engineers Jacksonville District	**	**
State of Florida		
South Florida Water Management District	***	****
Urban Coastal Counties[a]	***/*	***
Rural Counties[a]	*	?

Rankings:	
Well Developed:	****
	***
	**
Not Developed:	*
Insufficient Information:	?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 3. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Quality

INSTITUTIONAL ATTRIBUTES

CASE STUDIES Key Organizations	Financial Resources	Expertise	Political/Social/Legal Factors				Responsiveness	
			Statutory Authority/ Political Power	Geographic Jurisdiction	Regulatory Enforcement Authority	Public Accountability	Proactive	Reactive
Tennessee River Basin:								
Tennessee Valley Authority								
Power Operations	****	***	*	**	**	**	**	**
Nonpower Operations	**	****	**	**	**	***	**	**
South Florida:								
U.S. Army Corps of Engineers								
Jacksonville District	***	***	**	****	*	?	**	**
State of Florida								
South Florida Water Management District	****	***	***	****	**	***	****	****
Urban Coastal Counties[a]	***	***	***	**	***	?	***/**	***/**
Rural Counties[a]	**	**	***	**	**	?	?	**

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

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Table 3. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Quality (continued)

CASE STUDIES	INSTITUTIONAL ATTRIBUTES					
	Technical Information		Planning and Investment Criteria Based Upon Historic Climate Variability	Organizational Adaptation Addressed by Current Planning	Organizational Coordination	
Key Organizations	Acquisition	Utilization			Internal	External
Tennessee River Basin:						
Tennessee Valley Authority						
Power Operations	****	**	**	***	**	?
Nonpower Operations	****	**	***	***	****	***
South Florida:						
U.S. Army Corps of Engineers						
Jacksonville District	?	**	**	**	?	?
State of Florida						
South Florida Water Management District	****	****	***	****	****	****
Urban Coastal Counties[a]	***/**	***/**	?	***/**	***/**	***/**
Rural Counties[a]	?	?	?	?	?	?

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 3. Institutional Capacity to Adapt to Climate Change Impacts Related to Water Quality (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES	
	Organizational Awareness of Potential Climate Change Impacts	INSTITUTIONAL CAPACITY TO ADAPT TO CLIMATE CHANGE
Tennessee River Basin:		
Tennessee Valley Authority		
Power Operations	***	**
Nonpower Operations	***	**
South Florida:		
U.S. Army Corps of Engineers		
Jacksonville District	**	**
State of Florida		
South Florida Water Management District	***	****
Urban Coastal Counties[a]	**	***
Rural Counties[a]	*	?

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 4. Institutional Capacity to Adapt to Climate Change Impacts Related to Sea Level Rise

INSTITUTIONAL ATTRIBUTES

CASE STUDIES			Political/Social/Legal Factors				Responsiveness	
Key Organizations	Financial Resources	Expertise	Statutory Authority/ Political Power	Geographic Jurisdiction	Regulatory Enforcement Authority	Public Accountability	Proactive	Reactive
Apalachicola Estuary and Bay:								
NOAA/Estuarine Reserve	***	**	***	****	*	***	****	***
U.S. Army Corps of Engineers								
Mobile District	****	****	****	****	****	****	*	****
State of Florida								
State Agencies	****	****	****	****	****	****	****	****
Apalachicola Local Government	*	*	***	****	*	****	*	**
South Florida:								
U.S. Army Corps of Engineers								
Jacksonville District	****	****	****	****	****	?	*	****
State of Florida								
South Florida Water Management District	****	****	**	****	****	****	***	****
Urban Coastal Counties[a]	***/**	***/**	***	****	***/**	?	***/**	****/***
Rural Counties[a]	**	**/*	***	****	?	?	?	?

(continued)

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

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[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

Table 4. Institutional Capacity to Adapt to Climate Change Impacts Related to Sea Level Rise (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES Technical Information Acquisition	 Utilization	 Planning and Investment Criteria Based Upon Historic Climate Variability	 Organizational Adaptation Addressed by Current Planning	 Organizational Coordination Internal	 External
Apalachicola Estuary and Bay:						
NOAA/Estuarine Reserve	****	***	****	****	***	****
U.S. Army Corps of Engineers						
Mobile District	****	****	****	****	****	****
State of Florida						
State Agencies	****	****	****	****	****	****
Apalachicola Local Government	*	*	*	*	*	*
South Florida:						
U.S. Army Corps of Engineers						
Jacksonville District	****	****	****	****	****	****
State of Florida						
South Florida Water Management District	***	****	***	***	****	***
Urban Coastal Counties[a]	****/**	****/**	****/**	***/**	?	?
Rural Counties[a]	?	?	?	?	?	?

(continued)

Rankings:

Well Developed:	****
	***
	**
Not Developed:	*
Insufficient Information:	?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

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Table 4. Institutional Capacity to Adapt to Climate Change Impacts Related to Sea Level Rise (continued)

CASE STUDIES Key Organizations	INSTITUTIONAL ATTRIBUTES	
	Organizational Awareness of Potential Climate Change Impacts	INSTITUTIONAL CAPACITY TO ADAPT TO CLIMATE CHANGE
Apalachicola Estuary and Bay:		
NOAA/Estuarine Reserve	****	***
U.S. Army Corps of Engineers		
Mobile District	***	****
State of Florida		
State Agencies	****	****
Apalachicola Local Government	**	*
South Florida:		
U.S. Army Corps of Engineers		
Jacksonville District	***	****
State of Florida		
South Florida Water Management District	***	****
Urban Coastal Counties[a]	**/*	***
Rural Counties[a]	**/*	?

Rankings:
Well Developed: ****
***
**
Not Developed: *
Insufficient Information: ?

[a] For some institutional attributes a range is stated where multiple organizations are included in a single category, e.g., Urban Coastal Counties.

and a national estuarine sanctuary designation; and (2) initiating the Interagency Management Committee to investigate sea level rise issues as they relate to Florida and to build up sea level rise technical expertise.

Both examples also speak to other strengths of the Florida agencies to adapt to climate change impacts: specifically, their in-house expertise and their excellent internal and external coordination. Much expertise and coordination, relating to the Apalachicola area, exists internally in each agency. Also, the Florida agencies are involved in external collaborative arrangements with states and other federal and local agencies. The 1983 ACF Memorandum of Agreement between the states of Florida, Alabama, and Georgia, and the Corps of Engineers, and the ongoing "308" ACF basinwide study are examples.

The Mobile District of the Corps of Engineers has a well-developed institutional capacity to adapt to climate change impacts related to sea level rise. The Corps is primarily a reactive rather than proactive agency, however. It undertakes water resources planning and management actions in response to congressional directives or initiatives from state, county, or local governments under authorized programs such as the beach renourishment program. The Corps' greatest adaptive capacities are their in-house technical expertise and experience relating to coastal flood protection and erosion protection structural measures and their financial resources. The Corps co-funds, with the individual states, structural projects germane to its mission. Much of this coastal protection work would not be done if the individual states had sole responsibility for financing.

The Mobile District's capacity to adapt to climate change-induced water shortages in the Apalachicola River is increasing. They rank high in the political/social/legal factors and in public accountability. Until recently, the Corps has had external coordination and public accountability problems in the Apalachicola region because of their indifference toward coordination with Florida agencies, Franklin County government, and the local populace. However, this situation has begun to change. In the last few years several top level Corps officials have recognized the necessity of coordinating and consensus building with local government and Florida agencies involved in the Apalachicola River Basin. The Corps, through its "308" planning, has begun to develop a more balanced perspective and awareness of the importance of the multiple uses and environmental values of the ACF system. However, the Corps shows signs of continuing to champion navigation on the Apalachicola River over environmental uses of the river. Nonetheless, increased awareness of multiple uses and environmental values should enhance the Corps' capacity to implement basinwide integrated management strategies.

A combination of institutional attributes of the Apalachicola National Estuarine Research Reserve suggest that its capacity to adapt to climate change impacts related to sea level rise and water shortage is also growing. The research reserve, while not having any regulatory authority, has the institutional benefit of excellent geographic jurisdiction and a proactive mission towards research and public education.

The primary financial resources for the research reserve come from the National Oceanic and Atmospheric Administration, which is a large agency that recently has had to deal with declining budgets. The reserve has a small staff, and thus, is limited in in-house expertise and its capacity for utilizing external technical information. Despite its small staff, the reserve has centered its efforts on external organizational coordination and enhancing its accountability to the local populace. With little staff to conduct research, the reserve has developed mechanisms to leverage technical information from other sources, such as university researchers, government agencies in Florida, and the Army Corps of Engineers. Finally, existing educational programs about the importance of the estuarine system can be used as models in educating the public about climate change impacts on the estuary.

The local Franklin County government ranks low in its institutional capacity to adapt to climate change impacts related to both sea level rise and water shortage. While it possesses excellent geographic jurisdiction for sea level rise impacts and less so for water shortages, it lacks adequate financial resources and in-house expertise. More importantly, it lacks adequate external coordination mechanisms to allow it to work closely with other agencies in Florida. This is largely because Franklin County government and the local townspeople of the Apalachicola Bay area are critical and suspicious of the increased regulatory and enforcement presence of Florida agencies in the Apalachicola area.

Institutional Capacity - South Florida

The overview of institutional capacity to adapt to climate change for South Florida focuses on the South Florida Water Management District, the U.S. Army Corps of Engineers, and county governments in the region. The assessment of state agencies included under the Apalachicola Estuary and Bay case study is applicable to South Florida for the most part.

Awareness of the potential impacts of climate change is a major constraint across all of the institutions for all four impacts. None of the institutions is ranked as well developed for this attribute. Only the South Florida Water Management District is ranked as having a relatively high level of awareness for all four climate change impacts. Institutional capacity appears adequate for potential water shortage, water surplus, and sea level rise impacts, although the capacity is primarily that of the Water Management District in the case of water surplus and shortage and the Corps of Engineers for sea level rise. Institutional adaptive capacity is least assured for potential water quality impacts of climate change. This reflects the current fragmentation of responsibility and authority for water quality management in the state. While recent trends suggest an increasing role for the South Florida Water Management District, the district lacks sufficient regulatory authority at present.

The distinction between urban coastal counties and rural counties is principally a function of financial resources and expertise, which in turn are largely a function of demographics. The urban coastal counties, including Palm Beach, Broward, Dade, and Lee, are densely populated or rapidly growing. The rural counties, which include Monroe, Collier, Hendry, and Glades, have much smaller populations and property tax bases, and lower growth rates. With the exception of the Keys in Monroe County, these counties have not had to confront water resource management problems of the magnitudes experienced by the coastal counties.

Detailed information was not collected for the rural counties as part of the case study. Thus, there is an inadequate basis to fully assess their institutional capacities. Detailed information was collected for three of the four urban coastal counties: Lee, Palm Beach, and Dade. As indicated by the mixed rankings in Tables 1-4, there is a range of institutional capacities among these counties for some of the institutional attributes.

The South Florida Water Management District is exceptionally well equipped to contend with the possible impacts of greenhouse gas-induced climate change, with the exception of sea level rise where its statutory jurisdiction is limited. The direct effects of sea level rise in coastal areas on property, infrastructure, and public services due to inundation and increased coastal storm impacts are outside the district's domain except where those impacts are associated with the primary drainage system and water supply. Within this limited span of sea level rise impacts, the district has well-developed adaptive capacity.

The district's ad valorem tax base, broad statutory powers, and extensive expertise provide an excellent foundation for responding to climate change. The inter-organizational and intra-organizational boundary spanning role of the district's Office of Resource Assistance, the use of matrix task forces for planning and problem solving, and the organizationwide commitment to proactive consensus building will serve the district well in contending with the potential impacts of climate change.

The only areas where the district's capacity is less than optimal are in water quality impacts and water surplus. In the case of water quality, the district is just beginning to develop a significantly increased role as a result of the 1987 State Surface Water Improvement and Management Act. Thus its expertise, data acquisition and utilization, and planning are not as fully developed as for example, water shortage. The district's capabilities also are constrained by its limited regulatory power over water quality. Direct regulatory control of water pollution sources is exercised primarily by the State Department of Environmental Regulation. Regulatory control of land uses that may affect water quality through nonpoint sources is primarily the domain of county and local governments.

The Water Management District's institutional capacity to adapt to water surplus impacts of climate change are limited only by the lack of a comprehensive analysis of the capacity of the flood control system to account for major changes in land use since design and construction of the system in the 1960s. Because a comprehensive analysis of the system is planned over the next several years, this is only a short-term constraint.

Awareness of potential climate change impacts within the district is relatively high compared to many other state and regional water management institutions. Key individuals within the organization have a sense of the broad implications of climate change for water resources management in South Florida and information gaps that must be filled to raise climate change to a higher level of priority in the district's planning and decision-making process.

The information base for rating the institutional capacity of the Corps of Engineers is considerably less than that for the South Florida Water Management District. South Florida is part of the jurisdiction of the Jacksonville District. The rankings in Tables 1-4 generally reflect information on the Corps at the district level.

The Corps is primarily a reactive rather than proactive agency. It undertakes water resources planning and management actions in response to congressional directives or initiatives from state, county, or local governments under authorized programs such as the beach renourishment program. The Corps' greatest adaptive capacities are in those areas of water resources management where it traditionally has been involved in South Florida: flood control and coastal erosion control. Its involvement in water quality and water supply management in South Florida has been recent and tentative. The Corps' awareness of potential impacts of climate change also appears to be recent and not significantly diffused through the organization at either the district or national levels.

DISCUSSION

Case Study Findings

The overall capacity of case study institutions to adapt to climate change is ranked in the last column in Tables 1-4. Under conditions of water surplus (Table 1), the South Florida Water Management District is the sole agency that is rated "Well Developed"; the remainder all are less developed. Information is insufficient for ranking aspects of rural counties in South Florida.

A different pattern exists under water shortage conditions (Table 2), in which lower scores are assigned local government in Apalachicola and the U.S. Army Corps of Engineers district responsible for South Florida. Florida's state agencies rate a "Well Developed" ranking overall in the Apalachicola case study as does the South Florida Water Management District. The remaining agencies rank a little lower with the exception of South Florida's rural counties, for which there was insufficient information for evaluation.

Only two case studies are evaluated for water quality conditions (Table 3). In sharp contrast to the TVA, which has one *, the South Florida Water Management District exhibits a superlative capacity to adapt to climate change impacts in this category. For South Florida, the Corps is ranked low.

Institutional capacity to respond and adapt to sea level rise (Table 4) is assessed for the Florida case studies only. In both Apalachicola and South Florida the Corps scores high. In addition, Florida's state agencies, including the South Florida Water Management District, score high. On a local government level, South Florida's urban coastal counties are ranked higher than Apalachicola's local government, which scores a "Not Developed."

The case study assessments underscore the summary points discussed in the case studies. With respect to the TVA, the assessment reflects the agency's close adherence to its enabling statute and its historical emphasis on power, navigation, and flood control. In these primary mission areas, the agency has exhibited a strong level of technological leadership and innovation. In areas such as water quality, the agency, which acknowledges the fundamental importance of water quality issues, is less able to provide strong leadership in the region as a result of several institutional constraints. In addition to the absence of a clear legislative mandate to address water quality, responsibilities for water resources planning and management are fragmented vertically across multiple levels of government and horizontally across multiple jurisdictions. Moreover, severe obstacles to practicing coherent planning and management arise from inadequate data and financial resources, public apathy, and traditional land use practices.

Successful adaptation in the Apalachicola case study is contingent to a large degree upon productive interstate cooperation among Georgia, Alabama, and Florida for the overall Apalachicola-Chattahoochee-Flint River drainage basin. Florida's water management agencies are greatly constrained by planning and management actions in the upper ACF drainage basin by the Corps and the other two states. The success of recent initiatives among the three states and the Army Corps' Mobile District to protect the estuarine fishery resources reflects the critical need to further integrate environmental information and basin wide planning into regional water resources management.

Another key finding from the Apalachicola case study is the limited capabilities local governments have in developing and managing critical resources. Despite the importance of fishery resources to local and regional economies, a necessary role for the State of Florida is shaped by the need for greater technical experts, more bureaucratic education on the potential impacts of climate change, more resources, and improvements in capital infrastructure than can be provided by local governments. Moreover, without the mechanism available through the Coastal Zone Management Act for establishing an estuarine research reserve, the overall quality of the fishery resources would have been further imperiled.

Institutions in South Florida vary in the degree to which they carry out sound water resource management. In contrast to the well-developed capacity of the South Florida Water Management District to coordinate its activities with urban counties, the rural counties, such as Monroe County which includes the Florida Keys, have remained reluctant to implement environmental plans. Despite designation as an Area of Critical State Concern, Monroe County has sought to limit state authority and thwart state planning objectives.

Complementary Institutional Roles for Climate Change Adaptation

The case study results suggest that different levels of government may have particular roles in climate change adaptive strategies that are best suited to their resources, powers, and jurisdictional authorities. Coordination among public agencies at different levels of government is also essential. A proposed scheme of appropriate local, state, and federal roles follows.

Local Governments

- Coordinate or centralize (e.g., at the county level) the management of climate-sensitive natural resources that are currently managed by subcounty governments and special districts (water supply and drainage districts).

- Integrate climate change adaptive strategies into the planning process with specific attention to land and water use, economic development, capital (infrastructure) development, and natural hazard (e.g., hurricane, flooding) mitigation planning in cooperation with substate regional, state, and federal agencies with complementary powers and jurisdiction (e.g., Florida water management districts, state emergency management agencies, TVA, regional planning councils).

- Revise regulatory mechanisms to effect the objectives of strategic planning for climate change adaptation, especially in areas where local government jurisdiction is primary such as land use control.

- Participate in the development and operation of a state-level information acquisition and utilization network with substate regional, state, multi-state regional, and federal organizations for climate change information pertinent to local government roles in climate change adaptation.

- Develop or amend educational programs to promote greater public awareness about climatic change and its implications for society.

State Governments

- Develop or enhance basinwide water resources management and planning capabilities within the state.
- Develop coordinating mechanisms with other states and appropriate federal agencies where drainage basins extend beyond state boundaries or into major federal land holdings.
- Develop the capacity to achieve statewide land and water management objectives through regional and local planning and regulation that is consistent with state policies.
- Promote conjunctive management of the quality and quantity of surface and ground water resources.
- Coordinate statewide strategic planning for climate-sensitive resources (e.g., hurricane mitigation, coastal erosion mitigation, flood protection, drought management) that involves substate regional and local agencies.
- Develop and maintain an information acquisition and utilization network, including the necessary technical expertise, with substate regional, state, multi-state regional, and federal organizations for climate change information and public education pertinent to state and substate government roles in climate change adaptation.
- Sponsor and fund research on climate-sensitive state resources needed to supply information for the state-level climate change information system (e.g., fully characterize state ground water resources, determine the climate sensitivity of major natural resource-based economic sectors, vulnerability of coastal areas to accelerated sea level rise).

Federal Government

- Participate with the states to develop a climate change information acquisition and utilization network, including the necessary technical expertise to assist with public education and awareness programs.
- Sponsor and fund research and demonstration projects to enhance the ability to predict and detect climate change impacts on a regional level and to enhance development of planning and management strategies by federal, state, and substate governments for climate change adaptation, including structural mitigation alternatives.
- Strengthen coordination mechanisms among federal agencies and between federal agencies and the research community for detecting climate change impacts and for conducting and sponsoring climate change research.
- Encourage and support the development of water resource management coordinating mechanisms among states and appropriate federal agencies where drainage basins extend beyond state boundaries or into major federal land holdings.

Implications for the Southeast

The case study research findings, in conjunction with the above-mentioned roles for institutional adaptation, suggest several implications for the larger Southeastern region. Although any findings based upon three case studies are subject to extensive qualifications, some generalizations appear consistent with the evidence. First, environmental planning and management agencies would be well advised to examine closely Florida's system of water management districts and adopt similar guidelines and procedures where appropriate. The district approach, based upon hydrologic regions and ad valorem taxing powers, provides a socially responsive and environmentally sound basis for managing water resources. The major limitations to the WMD approach are encountered in areas such as Apalachicola where much of the watershed lies outside the regional WMD's jurisdiction. A notable exception to this approach is characterized by the TVA, which presently favors increased use of basinwide management strategies for water quality enhancement.

A second implication for the Southeast concerns local government capacity. Apalachicola's primary economic resource as well as its surrounding environment are likely to be severely damaged by potential climate change impacts. With the demise of the oyster industry from heat stress and saline intrusion, the town of Apalachicola will enter into yet another phase in its historical pattern of changing livelihoods. The distinction in this case is that anticipatory plans and programs can be developed ahead of time, rather than remain unprepared. In this regard, the state agencies have demonstrated a keen level of program planning and coordination. For other locales similar to Apalachicola, Florida is well-equipped to undertake actions which could minimize the negative impacts associated with climate change. For the Southeast in general, local governments will be subject to similar threats. A prudent strategy for southeastern states to pursue would be to develop and strengthen state-local government coordination and planning capabilities. Included in this list would be measures for public involvement, acquisition and use of technical information by qualified professionals, and a clear mandate to address issues germane to climate change.

The Apalachicola case study also highlights the importance of interstate coordination and cooperation for developing coherent responses to climate change. In regions where drainage basins encompass more than one state, coordination among and between water resource supply and demand activities is likely to become increasingly important for adaptation.

Finally, the case study results reinforce a leading role for the federal government. Federal agencies such as the National Oceanic and Atmospheric Administration and the U.S. Army Corps of Engineers perform vital and important functions in the case study regions. The TVA performs similar roles in its seven-state region. Federal agencies can provide a firm basis for research, sponsor demonstrations, and help public awareness. They are also important as a credible source of detecting the onset of climate change impacts. As more detailed studies of potential climate change impacts are initiated, federal agencies, such as the EPA, can be expected to play a larger role in assisting states and regions conduct research, help promote and support public education about climate change, plan alternative courses of action, and undertake structural or nonstructural solutions.

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